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ABSTRACT

The study analyzed short-and long-term memory processes in learning disabled (LD) children and compared them with normally achieving peers. Research on memory processes in LD children is reviewed and methodological limitations noted. Thirty-six normal and 36 LD Ss (8-11 years old) were asked to remember consonant trigams using one three encoding strategies (study, vocalization, and elaboration). Findings revealed that, overall, LD Ss recalled significantly fewer consonants than normal Ss. There were no significant differences in recall among encoding strategies. LD Ss also exhibited a significantly faster rate of forgetting and lower asymptotic level of recall. Contrary to expectations, LD Ss were at least actively involved in maintaining the information. Speculations are offered for the reason for LD Ss' slower rate of processing and greater interference. Educational implications, including training acquisition and retrieval strategies that can be quickly executed, are noted. (CL)

AN ANALYSIS OF PRIMARY AND SECONDARY MEMORY PROCESSES AND REMEDIATION OF POTENTIAL DEFICIENCIES IN LEARNING DISABLED AND NORMAL CHILDREN

by

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An Analysis of Primary and Secondary Memory Processes And the Effects of Encoding Strategies in Learning Disabled and Normal Children

Learning disabled (LD) children are those who experience problems in classroom learning but have no apparent physical, intellectual, or emotional defects as primary causes. It has been estimated that two-thirds of the children have reading and spelling problems; one half, arithmetic problems; one-half, handwriting difficulties; one-third, receptive language problems; one-fourth, expressive language problems; and one-fourth, concept confusions (Rocky Mountain Educational Laboratory, 1970). Thus, there is a high probability that difficulty in one area is associated with difficulties in others. Because of the prevalence of these problems, with estimates ranging up to 30% of the school population (Lerner, 1976), LD children have attracted a rapidly increasing amount of attention. Beyond the recognition that disabilities exist, little is definitively known about the kinds of problems which interfere with these children's learning (Torgesen, 1975).

A widespread and longstanding causal assumption has been that the difficulty in learning is one of several interrelated symptoms of an underlying brain abnormality, i.e., "the minimal brain dysfunction syndrome" (Clements, 1966). However, lack of any independent evidence of organic disorders in a great number of cases, along with recent disconfirming reports (Crinella, 1973; Routh & Roberts, 1972), makes this assumption tenuous. In addition, psychological processes that mediate LD children's poor academic performance have been poorly specified in experimental research. A large literature describes remediation techniques, rooted in speculation and with a paucity of rigorous research on causal relationships. One noted writer in this field has concluded:

> The field of learning disabilities is long on theory and short on facts (p. 13). . . .Too many methods currently used in the field are taught as if they were eternal verities, but they are based on the untested hunches of a few "recognized authorities," not on the results of research. (Ross, 1976, p. 167)

The present study emerges from a trend in the last three years designed to alleviate this situation by uncovering facts through research.

In 1968 the National Advisory Committee on Handicapped Children of the U.S. Office of Education proposed a definition of learning disabilities which became part of the Learning Disabilities Act of 1969. Although not without controversy (Mercer, Forgnone, & Wolking, 1976), this definition has been the most widely adopted in delineating this group:

> Children with special learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written languages. These may be manifested in disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic. They include conditions which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia, etc. They do not include learning problems which are due primarily to visual, hearing or motor handicaps, to mental retardation, emotional disturbance, or to environmental disadvantage.
>
> (United States Office of Education, 1968, p. 34)

Reference to basic processes is the most prominent factor in this definition. Yet, these process deficiencies remain vague and poorly defined. Hammill (1972) has stated that it is doubtful if authorities in the field of learning disabilities could come to any consensus on the nature of the process component. Consequently, despite the wide acceptance of this definition, there have been many differences in its interpretation and in diagnosis of children who meet the specified criteria (Bryant, 1974).

There is evidence which suggests that one of the process deficiencies involves memory. Clements (1966), in an extensive review of clinical literature, listed "disorders of memory and thinking" as one of the 10 most frequently mentioned symptoms of LD children. Rugel (1974) reviewed 25 studies which reported WISC subtest scores of reading disabled children. Following the suggestion of Bannatyne (1968), based on factor analyses, the subtests were reclassified into categories labelled Spatial, Conceptual, and Sequential rather than the traditional Verbal and Performance groupings. Children were ranked from low to high on their relative strength in these three categories. In the samples of disabled readers, the Spatial category received the highest rank, the Conceptual category the intermediate rank, and the Sequential the lowest rank significantly more frequently than they received the other ranks. No comparable pattern was found for the samples of normal children. On the Sequential category, disabled readers showed a marked deficit compared to normal readers. Since the tests comprising the Sequential category (Digit Span, Coding, and Picture Arrangement) supposedly require the ability to retain sequences of auditory and visual stimuli in short-term memory (Bannatyne, 1968), Rugel (1974) suggested that reading disabled children are deficient in this process.

In view of the above, a limited number of experimental investigations of memory with LD children have begun to appear. Most of these are marked by methodological problems, inconsistent results, or tenuous conclusions.

The purpose of the present study was to analyze short- and long-term memory processes in LD children and to compare them with normally achieving peers. It is assumed that the understanding of basic processes, such as memory and attention, is necessary for remediation. If deficiencies in basic processes exist, they may compound other, possibly higher-level areas of functioning and frustrate remediation efforts. In the related field of mental retardation, systematic and intensive research efforts in the area of memory have been fruitful in providing understanding on a theoretical level (e.g., Ellis, 1970; Scott & Scott, 1968) and possible implications for remediation techniques (e.g., Brown, 1974; Butterfield, Wambold, & Belmont, 1973).

Theoretical Foundations in Memory

The following section provides the basic theoretical framework for the present investigation. The evidence is strong that there are two factors in memory (Craik & Levy, 1976; Crowder, 1976), roughly corresponding to short-term and long-term memory, which in acknowledgment of William James (1890) are referred to as primary memory and secondary memory, respectively. Although there are differences in the interpretation of these factors (Atkinson & Shiffrin, 1968; Craik & Lockhart, 1972), recent analyses indicate the differences are mainly in terminology and emphasis (Craik, 1979; Glanzer & Koppenaal, 1977; Shiffrin, 1975).

In the conception adopted in the present research, primary memory is considered to be of brief duration and of limited capacity (Posner, 1966; Shiffrin, 1976). Transfer to secondary memory, which is considered to be of permanent duration and of unlimited capacity, is primarily a function of active processing of information. Rehearsal strategies are voluntary control processes (Atkinson & Shiffrin, 1968, 1971). Whenever there is transfer or copying into secondary memory from primary memory, there is also maintenance in primary memory (Waugh & Norman, 1965). Consequently, recall of an item can be based on information from primary memory, secondary memory, or both. However, since primary memory is limited in the number of items it can hold or process, additional items eventually fill capacity such that new information displaces the old. Then recall of old information is dependent upon secondary memory alone (Crowder, 1976). It is generally acknowledged that most tasks require some combination of both primary and secondary memory, and it is important to estimate the relative contribution of each.

In a theoretical paper, Torgesen (1977b) posited that most performance deficits of LD children are based on either their inability to employ efficient, task-appropriate cognitive strategies or their lack of awareness that such strategic behavior is effective. This is very similar to a position advocated by Brown (1974, 1975), that the performance of developmentally young individuals, i.e., children and the mentally retarded, is marked by a deficiency in strategic behavior. In the present framework, strategy deficiencies in LD children would be most likely evidenced by reduced performance in the secondary memory component of memory tasks. Some of the memory literature with LD children provides information on this issue.

Memory Research in Learning Disabilities

The following review focuses on investigations with the potential to contribute to knowledge on the primary and secondary memory components and cognitive strategies in LD children. Because a comprehensive review of memory literature with LD children has yet to be published and because studies have appeared in a wide variety of journals, those selected will be described in expanded form. Although some studies differ in the specific labels attached to their experimental groups and the specific criteria which define those labels, all labels refer generally to children who test in the normal range on intelligence tests but who experience difficulty, usually one or more years behind grade expectancy, most often in reading and sometimes in other academic areas as well. In all studies, chronological ages of the normal children are comparable to those of the LD children. For ease of explanation, studies are grouped according to task and each task is analyzed with reference to primary and secondary memory.

Free recall studies. Serial position curves from free recall tasks are considered to reflect the effects of the two memory components (Craik & Levy, 1976; Crowder, 1976; Glanzer, 1972). The superior recall of the most recently presented items represents output from primary memory, while that of all other items is viewed as output from secondary memory. Enhanced recall of the earliest presented items over the middle items reflects a higher probability of the early items' transfer to secondary memory due to more time available for their rehearsal (Glanzer, 1972).

Marshall, Anderson, and Tate (1976) compared normal (mean IQ = 105) and LD (mean IQ = 97) children on single-trial free recall lists of 11 pictures each. The authors hypothesized that LD children are deficient in rehearsal strategies and, therefore, would remember fewer of the items at the beginning of each list (primacy) than normal children, while recall of items toward the end of the list (recency) would show no differences. Both groups yielded serial position effects with no significant differences between their primacy effects. The total recall of the normal children was greater than that of the LD children.

The data were analyzed, post hoc, by separating each group into the 15 oldest and 15 youngest. Older LD children (mean CA = 9.4 yrs) showed a greater recency effect than younger LD children (mean CA = 7.8 yrs), while their primacy effects were comparable. Older normal children showed a greater primacy effect than younger normal children. Their recency effects did not differ. The authors concluded that the initial hypothesis of differential rehearsal received no support. They then surmised that the superior total recall of normal children may have been due to a higher general IQ factor and that LD children had delayed, but not permanently impaired, memory development, based on the differences between age groups.

The interpretations of Marshall et al. must be viewed as tentative. They analyzed primacy effects as "long-term memory" and recency effects as "short-term memory" by collapsing data over the first four and the last four serial positions, respectively, a theoretically murky tactic. Glanzer and Razel (1974), in a survey of 32 independent studies, reported a mean estimate of primary memory capacity, which recency effects are supposed to reflect, as 2.2 items. The inclusion of positions near the middle of the list for both effects may have contributed to the failure to obtain serial position differences. Also, their finding of a performance difference on the recency portion between LD children in the two age groups, in the absence of any difference on the primacy portion, is difficult to reconcile on the basis of developmental findings. Hagen and Kail (1973), Hagen and Kingsley (1968), and Thurm and Glanzer (1971) provided clear demonstrations that substantial differences between age groups were restricted to the primacy portion of the serial position curve and that recency effects were comparable across age groups. The "explanation" of the overall LD-normal difference in terms of IQ is gratuitous, and the conclusion that memory development in LD children is merely delayed is not supported by their data.

Bauer (1977a) obtained tentative evidence for a rehearsal deficit in LD children (mean CA = 9.7 yrs). In a first experiment, normal and LD children were compared on free recall lists of 11 nouns each. There were delays of 0 to 120 sec, either filled with an irrelevant activity or unfilled, between the last word presented and the cue for recall. Compared to normal children, LD children were expected to show: (a) lower primacy and equal recency effects in immediate recall (0 sec delay), (b) lower primacy and lower recency effects after unfilled delays, and (c) lower primacy and equal recency effects after filled delays, as a result of differential rehearsal activity in the two groups. In immediate and delayed recall, normals had greater overall recall than LD children. All predictions were confirmed, however the presence of a floor effect in the recency data with filled delays of LD children obscures their interpretation. The author concluded that, although the results implicate deficient rehearsal in LD children, there is evidence they were attempting some rehearsal, since interpolated activity reduced their recency performance.

In a second experiment, normal and LD children were compared on free recall lists of 3, 6, 9, or 12 nouns, with unfilled delays of 0 or 30 sec. Recall of LD children was lower than that of normals for all list lengths. For 3-word lists, the two groups were comparable with no delay, but LD children were inferior to normal children with a 30-sec delay. Bauer (1977a) interpreted this as showing comparable attention but deficient rehearsal in LD children. For 6-word and 9-word lists, primacy of LD children was lower than that of normal children, but recency was comparable, both with and without an unfilled delay. Reduced primacy in LD children is consistent with a rehearsal deficit, but equivalent recency between groups with a delay is not consistent and does not corroborate the results of the first experiment. For 12-word lists, primacy of the two groups was comparable, but recency of LD children was lower than that of normal children on delayed recall trials. Reduced recency on delay trials in LD children is consistent with a rehearsal deficit. However, comparable primacy between groups is not consistent with this and does not corroborate the results of the first experiment.

In another study, Bauer (1977b) tested attentional and rehearsal deficit explanations of learning disabilities. A first experiment compared normal and LD children's (mean CA = 9.8 yrs) recall of 3-letter lists with either filled or unfilled delays of 1, 3, 6, 12, and 18 sec. Normal children's recall was perfect across unfilled delays, while LD children's recall decreased to approximately 71% at the longest delay. Normal children performed better than LD children at the two longest filled delays. At the two longest delays, both normal and LD children showed higher recall when the delay was unfilled than when filled. These results suggest that LD children may have been attempting rehearsal but doing so less effectively than normal children.

A second experiment compared normal and LD children's recall of 3-word lists with unfilled delays of 0 to 30 sec. With immediate recall, the two groups were comparable, but with delayed recall LD children were inferior to normal children. Normal children's immediate and delayed recall were comparable,while LD children's delayed recall was lower than their immediate recall. These results again implicate a rehearsal deficit in LD children. However, in both experiments the to-be-remembered items were read aloud to the children. Vocalizing has been identified as an encoding strategy which facilitates short-term retention (Tell, 1971). Penney (1975) showed that auditory presentation of verbal stimuli results in comparable facilitation. Thus, Bauer's (1977b) finding of no differences between groups at short delays may have been a function of providing mnemonic support which benefits LD children more than normal children, since normal children may spontaneously use a strategy providing similar support.

Bauer (1977a, 1977b) ignored the inconsistencies within his own data and between his and other data (Marshall et al., 1976). Overall his data provide tentative support for the contention that rehearsal activities of LD children in memory tasks are less efficient than those of normal children. As a consequence, the most pronounced deficiencies appear to obtain in the secondary memory component of LD children.

Bryan (1972) also hypothesized that LD children are deficient in rehearsal strategies and predicted an important consequence: They will perform more like normal children when they are provided a strategy. She compared 15 normal and 22 LD children over 10 free recall trials on a single 15-item list. Children were presented the items either auditorily (words) or visually (picture referents of the words) under one of three conditions. Those in the Forced Rehearsal condition were required to pronounce aloud the items during presentation; those in the Voluntary Rehearsal condition were told it might help to say the items aloud; and those in the Attention condition were told to attend carefully to the items. The LD children performed more poorly than normal children with both modes of presentation, and there were no differences among the three rehearsal conditions.

Bryan did not report serial position data, thus restricting any inferences about specific memory components. No change in performance as a function of strategy is contrary to Torgesen's (1977b) strategy deficiency hypothesis and the contention of inferior secondary memory in LD children. However, these results must be interpreted with caution. The dependent variable was a child's greatest number correct on any one of the 10 trials. This is not a very sensitive measure. For example, a child in one condition who recalled 15 correct on Trial 4 would be scored the same as a child in another condition who recalled 15 correct only on Trial 10. With six between-subjects conditions, there were only 2, 3, or 4 children per cell, which also limits the conclusions. Finally, intellectual level and chronological age were not reported for either group.

Parker, Freston, and Drew (1975) studied mnemonic strategies of a different type. They gave normal and LD children (mean CA = 9.8 yrs) 12 single-trial free recall lists of five words each. Organized lists were comprised of words at one of three levels of objective frequency and from one of four conceptual categories. Unorganized lists at each level of word frequency contained no more than two words from the same category. The authors hypothesized that input organization would facilitate chunking as a control process and, as a result, facilitate recall for normal children (Drew & Altman, 1970) but that it would not be utilized by LD children (Freston & Drew, 1974). Normal children recalled more than LD children, but, since the predicted interaction failed to obtain, subanalyses were considered necessary. For both groups, recall was a function of word frequency, as expected. For normal children, recall of organized lists was greater than unorganized lists at intermediate and high but not low levels of word frequency. For LD children, recall was unaffected by input organization. The authors concluded that their hypothesis was supported. Serial position data, intellectual level, and chronological age were not reported and, in light of the failure to obtain the predicted interaction, their conclusions must be regarded as tentative.

Wilson (1977) compared fourth and fifth grade normal and LD children's free recall as a function of <u>subjective</u> output organization, i.e., inter-trial repetition of sequences of "unrelated" words (Tulving, 1962). A list of 12 high-frequency words was presented 12 times, each with a different word order. No reliable differences were obtained on total recall and subjective organization. The author concluded that LD children do not utilize experimenter-defined organization, but they subjectively organize items as effectively as normal children. However, this conclusion must also be regarded as tentative. It is possible that floor effects obscured any differences in output organization and in total recall, and serial position data, intellectual level, and chronological age were not reported.

Overall, studies of free recall indicate inferior memory in LD children. Although definite interpretation of the basis for this inferiority is not yet possible, some studies suggest deficient strategic behavior, i.e., rehearsal and/or organization, and as a result, inferior secondary memory.

Serial probe and related studies. A variety of tasks involve presenting a series of stimuli and subsequently testing for specific recall of order or position information. Recall of primacy and middle positions is considered to reflect output for secondary memory, while recall of recency positions reflects output from primary memory (Craik & Levy, 1976; Crowder, 1976; Ellis, 1970).

Tarver, Hallahan, Kauffman, and Ball (1976) investigated the development of rehearsal strategies over various ages of normal and LD children by analyzing the form of serial position curves from a serial probe task. Seven pictures were presented and then turned face down, one at a time in a row in front of each child. Memory for the position of a specific picture was tested immediately by the display of a "probe" picture identical to the targeted one. A child was to point to the position of the target picture.

In a first experiment, recall was greater for normal children than LD children (mean CA = 8.7 yrs). The serial position curve of the normals showed primacy and recency effects, while that of the LD children showed only a one position recency effect. Tarver et al. stated that the absence of a primacy effect is consistent with the hypothesis of deficient rehearsal in LD children. Hallahan, Kauffman, and Ball (1973) also found higher recall in normal children as compared to LD children (mean CA = 12.0 yrs) on a serial probe task. However, serial position data were not reported.

In a second experiment, intermediate-aged and older LD groups (mean CA = 10.2 and 13.5 yrs, respectively) were tested in either the previously described control condition or a rehearsal condition in which they were required to label, chunk, and rehearse items aloud. The older group recalled more than the intermediate group under both the control and the rehearsal conditions. Both groups displayed primacy and recency effects under both conditions. There were no significant differences between rehearsal conditions.

The lack of comparably-aged normal control groups makes further interpretation difficult.

Comparison of the LD group in the first experiment with the LD groups under control instructions in the second experiment revealed greater primacy effects for the two older groups. Tarver et al. concluded that this supported the hypothesis of a developmental lag in rehearsal strategies in LD children and that their performance can be improved by the provision of appropriate strategies. However, these conclusions must be viewed as tentative in light of the following considerations. The absence of a pronounced primacy effect by the younger children in the first experiment is in marked contrast to the results of the Marshall et al. (1976) study with comparably-aged children. In the second experiment, they did <u>not</u> obtain any change in primacy by providing rehearsal strategies. Also, they did not preclude the use of the presumed rehearsal strategies to produce a performance decrement. They did not manipulate rate of presentation to vary the amount of rehearsal time. These manipulations have been shown to provide supporting evidence for rehearsal deficits (Ellis, 1970). In addition, they did not discuss the lower recency effect over the last three positions, for which rehearsal strategies are presumably less important, for the youngest group. And they did not compare the performance of the older groups with control groups.

In a follow-up study, Tarver, Hallahan, Cohen, and Kauffman (1977) administered a serial probe task to LD adolescents (mean CA = 15.6 yrs). Both primacy and recency effects obtained. An overall analysis which included data of the 8-, 10-, and 13-year olds from the Tarver et al. (1976) experiments revealed that the two oldest groups recalled more in total than the 10-year olds who recalled more than the 8-year olds. However, the two oldest groups were not significantly better than the younger groups at the primacy positions relative to other positions, which would be predicted by a developmental lag hypothesis. No explanation was offered. Tarver et al. (1977) concluded that their series of studies provided strong support for the hypothesis of a developmental lag in verbal rehearsal strategies in LD children. The authors' conclusion would be stronger if, rather than comparing subjects from different studies, different age groups and normal controls were included in their study.

Pelham and Ross (1977) presented evidence contrary to the hypotheses of a developmental lag in rehearsal strategies and inferior secondary memory. They compared young, intermediate-aged, and older normal and reading disabled children (mean CA's = 7.1, 9.4, and 11.4 yrs, respectively) on a variation of the serial probe task. On each trial, all stimuli were presented simultaneously, rather than one at a time. After each position response, they were displayed again while the experimenter pointed to the correct position. Normal children recalled no more than reading disabled children. Serial position data were not reported. The results do not corroborate the previous findings of recall differences. Possibly, these disparities may have been due to the task modifications. Since the stimuli were displayed simultaneously as an array and recall was probed immediately after presentation, it is possible that performance was based mainly on primary memory. Primary memory is widely considered to vary minimally across a variety of individual difference variables (Crowder, 1976; Glanzer, 1972). Therefore, if primary memory is not inferior in LD children or if the task is not sensitive to the differences, no recall differences between reading disabled and normal children would be expected.

Spring and Capps (1974) viewed a possible memory deficiency in LD children from a different perspective. They hypothesized that dyslexic (reading disabled) children have a memory deficiency attributable to slow speech-motor encoding during an item's presentation. If more time is required for an item to enter the memory system, there is less time available for its rehearsal and, consequently, a lower probability of its availability in secondary memory. Dyslexic and normal children were compared on a serial probe task with digits as stimuli. Visual scanning patterns were observed during presentation of the probe. The authors stated that adults who use a cumulative rehearsal strategy typically scan forward from the first stimulus, stopping at the card of their choice. Children were also compared on encoding-speed tasks, in which they rapidly named either randomly sequenced digits, color patches, or line drawings. The authors predicted that dyslexic children, as compared to normal children: (a) would recall fewer items from all but the recency positions, (b) would be slower on the naming tasks, particularly with verbal stimuli (i.e., digits), and (c) would employ forward scanning less frequently. In addition, high correlations between encoding speed and recall and between encoding speed and forward scanning were expected. Children were divided into young (8.6 to 10.0 yrs), intermediate-aged (10.1 to 12.0 yrs), and older (12.1 to 13.4 yrs) groups.

On the naming speed tasks, dyslexic children were slower than normal children, and color and picture naming were slower than digit naming. There were larger differences between dyslexic and normal children on digit naming than on color and picture naming. Spring and Capps suggest these differences may be due to greater practice of verbal encoding by normal children.

On the serial probe task, there were more left-to-right scanners among the normal children (23 out of 24) than among the dyslexic children (13 out of 24). Dyslexic children recalled fewer items than normals at all but the recency positions. It appears from graphed data that LD scanners evidenced a primacy effect though lower than that of normal children, while those who did not scan from left-to-right (hereafter called "nonscanners") showed no primacy effect at all. Also, nonscanners displayed a superior recency effect to that of scanners. The performance of scanners was statistically different at different serial positions, but subanalyses to determine whether it was at primacy, recency, or both were not reported. These results suggest that fewer dyslexic children cumulatively rehearse than normal children and for those who do, rehearsal is more limited. Unexpectedly, the correlation between scanning (and presumably rehearsal) and digit naming speed was not significant, while the correlation of scanning with color/picture naming was significant. Significantly, digit naming speed and scanning together accounted for 91% of the variance in secondary memory performance.

This study is interesting in its choice of measures and their implications. A methodological complication exists in that, while two-syllable digits (0 and 7) were intentionally excluded on the digit naming task, the color naming task included one two-syllable color out of seven different colors and the picture naming task included one three-syllable and four two-syllable pictures out of 25 different pictures. This might have contributed to the differences or have interacted with other variables. Mean chronological age for all groups and intellectual level for the normal groups were not reported. Spring and Capps concluded that primary memory is equivalent for dyslexic and normal children but that secondary memory is impaired for dyslexic children because their slow encoding either limits or occupies the time available for rehearsal.

Spring (1976), in an extension of his hypothesis, predicted that digit span performance would fail to account for a significant portion of the variance of reading ability beyond that accounted for by speech-motor encoding speed. Serial recall tasks such as digit span are considered to reflect individual differences in ability to transfer information from primary to secondary memory (Glanzer, 1972). A person's responses displace items from primary memory, leaving recall based largely on secondary memory. All effects obtained in the previous study on the naming speed tasks were replicated. On the digit span tasks, dyslexic children were inferior to normal children. Digit naming speed and digit span accounted for 53% of the reading ability variance. However, each alone also accounted for significant portions. Thus, digit span accounted for a small but significant portion of reading ability variance beyond that accounted for by naming speed, providing only partial support for the speech-motor encoding hypothesis. The results indicate that an additional source of variation affecting memory transfer contributes to the inferior memory span performance of reading disabled children.

Torgesen and Goldman (1977) derived a test of Torgesen's (1977b) strategy deficiency hypothesis by comparing normal and reading disabled children (mean CA = 8.1 yrs) on eight trials of a sequential recall task for which verbal rehearsal has been shown to be an effective mnemonic strategy (Flavell, Beach, & Chinsky, 1966). The experimenter held a series of seven line drawings of common objects in front of a child and pointed to a given number (from two to five) of them in a prearranged sequence. After a 15-sec delay, the child attempted to point to them in the same sequence. During the delay, the experimenter observed the child carefully for evidence of the use of verbalization or rehearsal, defined as instances in which the stimulus names were actually spoken or could be lip-read, and lip movements representing rehearsal but not identifiable as corresponding to specific words. Each child was then questioned to determine if he had done anything special to help remember the order of the stimuli. Finally, the task was administered again with the requirement that each child say aloud the picture names during both presentation and recall, with the expectation that the proposed differences between groups would be reduced if reading disabled children were trained in the use of a vocalization strategy.

On the first task, normal children both verbalized and recalled more than the reading disabled children. Fifteen of 16 normal children indicated they had used verbal rehearsal as compared to only 9 of 16 reading disabled children. For both verbalizations and recall scores, the reading disabled group made significant improvements between the first and the second task, while the normal children showed a non-significant increase. On the second task there were no significant differences between the two groups for both measures. The authors concluded that: (a) reading disabled children show poorer memory on a sequential recall task than normal children, (b) their failure to spontaneously make use of efficient rehearsal strategies is an underlying factor, and (c) their performance can be significantly improved if they are trained in the use of such strategies.

These conclusions seem basically sound, and the data add some support to the contention that some LD children fail to efficiently transfer information from primary memory to secondary memory or to efficiently maintain information in primary memory (Torgesen, 1977b). However, Torgesen and Goldman's task analysis of an efficient strategy is suspect when out of eight possible opportunities, normal children who supposedly are task efficient averaged only 3.4 verbalizations, which resulted in a mean recall score of only 14.0 correct responses out of a possible 29

(LD children = 1.9 verbalizations and 10.3 responses). A question remains as to why, when provided the strategy, normal children did not improve significantly. Also, it is difficult tp assess to what degree strategy facilitation may be confounded by differential practice effects for the two groups. In addition, the only measures of intellectual level were scores on the Vocabulary subtest of the WISC.

Torgesen (1977a) extended the previous findings by comparing normal and reading disabled children (mean CA = 9.7 yrs) on free recall tasks under both control and strategy instruction conditions. The task employed lists of 24 line drawings of common objects, with six drawings from each of four conceptual categories. Several strategic behaviors were recorded during presentation of the items including re-positioning items (i.e., clustering) and vocalizing them. The children were also compared on a serial recall task under both control and strategy instruction conditions. The task used sequences of seven line drawings, each of which could be viewed individually when a child pressed a corresponding button below the stimulus. The children were to recall the names of the drawings in the order presented. Strategic behaviors that were recorded during item presentation included vocalizing, cumulatively rehearsing, pausing between button presses, and backward sequencing of button presses.

instructions. However, contrary to the original hypothesis, reading disabled children improved more than normal children on the free recall task only. For the study behaviors, there appeared to be no difference between groups (no analyses were mentioned). Only backward sequencing showed a marked change over the control condition, with LD children showing a greater reduction than normal children. However, floor effects in the normal children's data suggest that this may have been artifactual. This study partially supports the hypothesis that LD children are less efficient in strategy usage and consequently benefit more from strategy training than normal children.

Overall, the serial recall studies provide some support for the contention that LD children are less efficient in mnemonic strategies and, consequently, are less able to deal with stringent memory demands.

Conclusions. The most outstanding feature in the preceding review is the lack of methodological sophistication. The most frequent weakness of all memory studies of LD children is inadequate description of sample characteristics, such as chronological age or intellectual level (Bryan, 1972; Dornbush & Basow, 1970; Farnham-Diggory & Gregg, 1975; Gaines & Raskin, 1970; Lasky, Jay, & Hanz-Ehrman, 1975; Leslie, 1975; Lilly & Kelleher, 1973; McSpadden & Strain, 1977; Morrison, Giordani, & Nagy, 1977; Noelker & Schumsky, 1973; Parker et al., 1975; Ring, 1976; Spring, 1976; Spring & Capps, 1974; Stanley, 1976; Stanley & Hall, 1973; Wilson, 1977). Considering the characteristics used to delineate children with learning disabilities, it is important that some indices of intellectual level are reported. Otherwise, readers must take on faith the assumption that the experimental children are not definable as mentally retarded and that the control children are not of higher than average intelligence (Hallahan, 1975). Since many basic psychological processes may follow developmental trends, it is essential in establishing the course of the development and in comparing studies that chronological ages are reported. In addition, undoubtedly some of the differences in results between studies may be ascribed to differences in the classification criteria by which the samples were defined and selected. Another problem is the failure to include a normal comparison group (Camp, 1973; Camp & Dahlem, 1975; Estes & Huizinga, 1974; Freston & Drew, 1974; Gaines & Raskin, 1970; Hallahan, Tarver, Kauffman, & Graybeal, 1978; Lilly & Kelleher, 1973; Mercer, Cullinan, Hallahan, & LaFleur, 1974; Raskin, 1971; Swanson, 1977; Tarver et al., 1976; Tarver et al., 1977). To show that learning disabilities are related to an aspect of information processing, it must also be shown that this aspect does not characterize normal children (Torgesen, 1975).

These and the other methodological limitations mentioned in the review place serious restrictions on the strength of the conclusions that can be drawn from this research. However, a small nucleus of studies Spring and Capps (1974), Tarver et al. (1976, Experiment 1), and Torgesen and Goldman (1977) on serial recall held such qualifications to a minimum and their results are revealing. They indicate that LD children employ mnemonic strategies less efficiently, and consequently transfer less information into secondary memory, than normal children.

It is apparent that there is evidence to suspect the existence of some basic deficiencies, however it is also apparent that memory processes in LD children are not very well understood and have rarely been studied under rigorous experimental conditions. A more rigorous analysis was proposed in the present study.

The Task

A memory task was required which has been extensively researched and which affords both the potential to assess primary and secondary memory and the flexibility to manipulate mnemonic strategies. The task that was used involves a distractor technique which permits measurement of the retention of single items over short intervals of time, as first devised by Smith (1895) and rediscovered by Brown (1958) and Peterson and Peterson (1959)--and now referred to as the Brown-Peterson task. In the typical procedure, a person briefly views a to-be-remembered item, engages in a distracting activity during a short retention interval, and then attempts to recall the item. The task is sensitive to retroactive interference of the interpolated activity, proactive interference of prior trials, and intra-item interference. The somewhat surprising initial findings were that an item as short as three units would be forgotten within 18 sec if a person were prevented from rehearsing during the retention interval. This task has been heavily investigated in psychology and one eminent investigator has commented: "This is surely one of those areas of research and theory to which students of memory may point with some satisfaction" (Crowder, 1976, p. 216).

On the Brown-Peterson task, the obtained forgetting functions can be analyzed along the lines suggested by the dual process conceptual framework adopted in the present study. Generally, retention has been characterized by an initial <u>rapid decline</u>, stabilizing after several seconds at some <u>low asymptote</u> (Dillon & Reid, 1969; Posner & Rossman, 1965; Turvey & Weeks, 1975). The initial rapid decline reflects primary memory and the asymptote, secondary memory (Craik & Levy, 1976; Peterson, 1966). Figure 1 depicts typical results. Variables such as the type of encoding activity, the similarity of the to-be-remembered items, the difficulty of the distractor task, the similarity between the distractor items and the to-be-remembered items, and the length of the intertrial intervals have been shown to differentially affect primary and secondary memory

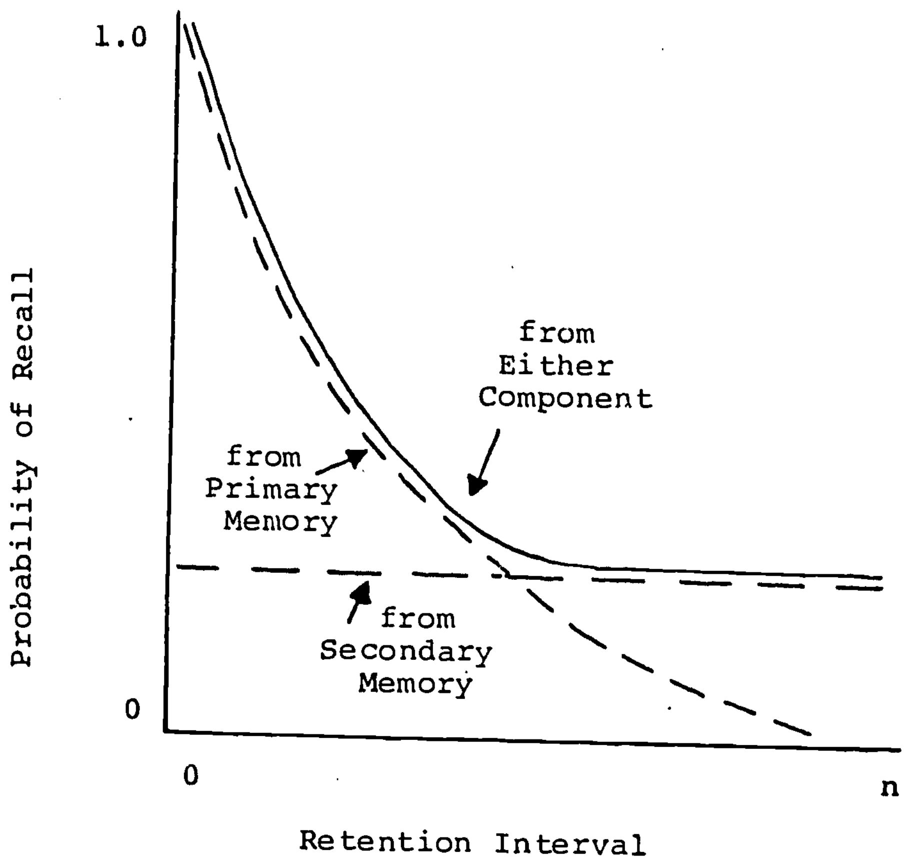

Figure 1. Probability of correct recall from primary memory, secondary memory, and either component as a function of length of retention interval in the Brown-Peterson task.

components. The choice of the Brown-Peterson task should not restrict the generality of the findings, for it has been shown that implications for primary and secondary memory can be generalized to other tasks such as free and probed recall (Glanzer, 1972; Waugh & Norman, 1965).

The present study investigated the course of forgetting in normal and LD children of comparable chronological age and intellectual level. Retention was measured after varying intervals in order to derive both slope and asymptote performance estimates. To provide a test of the contention that LD children are less efficient in cognitive strategies (Torgesen, 1977b), retention intervals were either filled with a distractor activity or unfilled (Dark & Loftus, 1976; Meunier, Ritz, & Meunier, 1972; Modigliani & Seamon, 1974).

General Research on the Effects of Encoding Strategies

In learning tasks, a child may engage in a variety of cognitive activities, some of which may be detrimental and some facilitative to later recall. It is possible, and the literature review provides some support, that LD children engage in activities that are less than facilitative. In the Brown-Peterson task, precise investigation of some of these activities is possible. The following review focuses on the studies of normal adults which have manipulated strategic behavior in the Brown-Peterson task. These studies are important in that they demonstrate the sensitivity of the task to strategic manipulations and provide a basis for the encoding strategies to be used.

Lindley and his associates (1963, 1965; Lindley & Nedler, 1965; Schaub & Lindley, 1964) studied the effects of providing specific encoding cues along with the to-be-remembered items on subsequent retention. Lindley (1963) presented capital letter trigrams, while encoding cues were additional lower-case letters in the appropriate positions to make a complete word (e.g., douBTLess). Encoding cues facilitated recall of low-meaningfulness trigrams, presumably through chunking, but interfered with recall of high-meaningfulness trigrams. The author suggested that high-meaningfulness trigrams were already encoded as an integrated chunk and that extra letters only interfered with their recall. Lindley and Nedler (1965) and Schaub and Lindley (1964) provided one group of individuals single-word associations to the to-be-remembered trigrams, <u>generated</u> by another group of individuals. Encoding cues facilitated recall for both high- and low-meaningfulness trigrams. Lindley (1965) provided either easy-to-decode encoding cues (i.e., the first three letters of the cue were the three letters of the trigram in the correct order), difficult-to-decode encoding cues (i.e., the letters of the trigram were interspersed with other letters of the cue), or no encoding cues. Ease of decoding facilitated retention. High-meaningfulness trigrams were recalled better than low-meaningfulness trigrams when the cues were absent, but this difference was eliminated when the cues were provided. The author suggested that the degree of memory facilitation provided by particular encoding cues may be a function of the degree of unitization (i.e., chunking) they provide and the complexity of the rules of decoding.

In the previous studies, encoding cues appeared to affect secondary memory, although the distinction between primary and secondary memory was not drawn. The procedure used was to provide specific encoding cues in an attempt to demonstrate facilitated recall. However, this leaves a person dependent either on external support or re-use of the same cues for later facilitation. It would appear that more flexible and generalizable effects could be accomplished by providing more general encoding strategies, from which individuals can generate their own specific cues in different contexts. The following studies employed variations of this procedure.

In a series of experiments by Tell (1971, 1972; Tell & Ferguson, 1974; Tell & Voss, 1970), the effects of a person's concurrent vocalization during presentation on the recall of consonant trigrams were investigated. Persons required to say aloud the trigrams at presentation were compared with those required to say aloud the words "three consonants." The latter was designed to suppress any covert vocalization of the trigrams during the presentation interval. Vocalizing the trigrams resulted in superior recall. Other experiments compared persons who vocalized the to-be-remembered items at presentation with those instructed to read them silently, at retention intervals of 2.7 sec and 10.8 sec. Vocalizing again resulted in superior performance and had its greatest effect at the shortest interval due presumably to the contributions of both auditory and articulatory cues to primary memory. It was concluded that saying and hearing oneself say something can be important sources of information and also potential sources of disruption.

Kintsch, Crothers, and Jorgensen (1971) directly investigated whether facilitation in recall, using a Brown-Peterson task, could be obtained by strategies that semantically process and chunk the to-be-remembered items or by semantic processing of each item separately. They also sought to determine the locus of the effect of encoding strategies in primary and secondary memory by testing at retention intervals of 3, 6, and 24 sec. In various experiments, they compared the recall of: (a) persons who said aloud each of the three to-be-remembered nouns, (b) those who said aloud each noun along with something based on its meaning (e.g., the noun and a suitable verb), (c) those who said aloud only something relevant to each noun's meaning (e.g., a suitable verb), and (d) those who said aloud only something irrelevant to each noun's meaning (e.g., "even" if the total number of letters in the word was an even number). Recall from primary memory was best for those who vocalized only the nouns (85.6%), intermediate for those who voiced something relevant in addition to the nouns (55.5%), and worst for those who voiced only something other than the nouns (42.3%, relevant; 36.0%, irrelevant). Recall from secondary memory was low and comparable in all conditions (24.3%).

In a final experiment, persons had to form sentences which in some way connected all three to-be-remembered nouns and say them aloud. Recall from primary memory was high and comparable to that of the condition in which only the nouns were voiced (90.0%). Significantly, recall from secondary memory was greatly superior to all other conditions and approximated the level of recall from primary memory (79.0%). The authors concluded that: (a) semantic processing does not produce better encoding and retention if it does not cause chunking of the items, (b) interference-free vocalization facilitates primary memory, and (c) interactive processing facilitates secondary memory.

Elliott (1973) provided support for some of the previous findings by instructing persons to say aloud four times the to-be-remembered noun trigram or to imagine a scene in which the things to which the words referred were interacting with one another. Interactive imaginal encoding instructions resulted in better recall than rote repetitive instructions. Since retention was tested only after 32 sec of interpolated activity, this facilitation presumably obtained in secondary memory.

Elmes and Bjork (1975) corroborated some of the results obtained by Kintsch et al. and by Elliott by instructing persons to engage in either rote repetitive rehearsal or interactive elaborative rehearsal of word pentads during the presentation interval. Retention intervals were 0, 4, and 18 sec. Overall recall was higher in the elaborative strategy condition than in the repetitive condition, and the superiority was specific only to the secondary memory component. Performance of an uninstructed control group paralleled that of the repetitive condition, indicating that when individuals are left on their own, they may actively rehearse but in a manner which is less than optimally efficient.

In summary, studies in the general memory literature which have manipulated encoding strategies using the Brown-Peterson task have shown that vocalizing to-be-remembered items often has facilitative effects on primary memory, while strategies which elaborate and chunk items facilitate secondary memory.

The literature suggests that LD children are less efficient in using strategies to encode information for later recall than normal children (Torgesen, 1977b).

However, there are many problems in these investigations. In addition, the majority of them base inferences on cognitive strategies only on gross performance (cf. Belmont & Butterfield, 1977). Of the few which employed a direct instructional approach, two obtained no effects of the instructed strategies (Bryan, 1972; Tarver et al., 1976), one found mixed effects (Torgesen, 1977a), and only one showed unequivocal facilitation of retention (Torgesen & Goldman, 1977). It would be important to demonstrate that the performance of LD children can be facilitated by trained cognitive strategies, thereby providing a basis for elaborated remedial techniques and increasing confidence in the proposed cognitive deficiencies.

Statement of the Problem

Although concern for remediation of learning disabilities in children has increased rapidly in recent years, knowledge of the types of processes which prevent children from learning effectively has lagged far behind (Torgesen, 1975). There is suggestive evidence in clinical literature (Clements, 1966; Rugel, 1974) that their deficiencies may involve memory processes.

Experimental investigations of memory in LD children have been frequently marked by methodological limitations and inconsistent results. However, studies by Spring and Capps (1974), Tarver et al. (1976, Experiment 1), and Torgesen and Goldman (1977) indicate that LD children's recall is inferior to that of normal children and that this may be a result of inefficient use of cognitive strategies. The suggestion is that primary memory is equal in normal and LD children but that secondary memory is inferior in LD children. Of the few investigations which employed a direct instructional approach, only one showed a definite effect of providing a strategy (Torgesen & Goldman, 1977).

The fact that previous research has not determined with confidence the existence and the source of differences between normal and LD children on memory tasks was the impetus for the present investigation. The objective was to provide a rigorous analysis of primary and secondary memory processes and of the effects of mnemonic encoding strategies in normal and LD children. The task used to accomplish this has been extensively researched and is well-accepted by general theorists. Children were presented to-be-remembered consonant trigrams, followed by variable-length retention intervals, and a cue for recall. During the presentation interval, children employed one of three encoding strategies: (a) Vocalization, in which the to-be-remembered letters were said aloud (designed to affect primary memory; Tell, 1972), (b) Elaboration, in which any words which began with the to-be-remembered letters and which were conceptually related were said aloud (designed to affect secondary memory; Kintsch et al., 1971), and (c) Control, in which a child was uninstructed in any specific strategy. The retention intervals were either filled with a rehearsal-distracting task or unfilled (Dark & Loftus, 1976; Meunier et al., 1972; Modigliani & Seamon, 1974).

Previous research with LD children suggests that their overall recall would be lower than that of normal children.

After unfilled retention intervals with instructions to study the items during presentation (Control), it was expected that normal children would show little retention loss. The LD children were not expected to differ from normal children at shorter intervals (i.e., in primary memory) but would show greater loss at longer intervals (i.e., in secondary memory). This is based on Torgesen's (1977b) strategy deficiency hypothesis.

After filled retention intervals with Control instructions, normal and LD children were expected to show comparable recall at the shorter intervals, while LD children were expected to be inferior at longer intervals. This follows from equivalent recency effects between groups in the studies by Spring and Capps (1974) and Tarver et al. (1976) and Torgesen's (1977b) strategy deficiency hypothesis. However, the difference between recall after filled and unfilled retention intervals was expected to be smaller for LD children than for normal children. Presumably, normal children's recall is more a function of rehearsal activities which are adversely affected by the activity interpolated in the retention intervals (Bauer, 1977a, 1977b).

With instructions to say aloud the items during presentation (i.e., Vocalization) and after filled retention intervals, LD children, who are assumed to employ less efficient mnemonic strategies (Torgesen, 1977b), were expected to improve more than normal children from performance in the Control condition.

After filled retention intervals with instructions to elaborate the items into conceptually related words (i.e., Elaboration), normal and LD children were expected to show superior secondary memory to that in the other conditions.

Interactive elaboration has been shown to greatly facilitate secondary memory (Elliott, 1973; Elmes & Bjork, 1975; Kintsch et al., 1971). It was also expected that LD children in the Elaboration condition would show equivalent or superior retention to that of normal children in the Control condition who were uninstructed in any specific strategy.

Method

Subjects

The subjects were 36 normal and 36 LD Caucasian children, between the ages of 8.5 and 11.5 yrs, selected from six county elementary schools and randomly assigned to three encoding strategy conditions. Children classified as learning disabled were chosen from those who qualified for special services by the Tuscaloosa County Board of Education, who scored no less than one standard deviation below the mean on the Wechsler Intelligence Scale for Children--Revised or the Stanford-Binet Intelligence Scale, and who performed at least one year below grade expectancy in reading and one half year below grade expectancy in mathematics, as measured by individual diagnostic tests, i.e., the Sucher-Allred Reading Placement Inventory (Brigham Young University Press, Salt Lake City, Utah) and The Key Math Diagnostic Arithmetic Test (American Guidance Service, Inc., Publisher's Building, Circle Pines, Minnesota). (One exception was a child in the Control condition who was 3.0 yrs behind grade level in reading and who was at grade level in mathematics.) They also had to be free of gross physical, sensory, and emotional problems.

Normal children were chosen from those with an IQ score plus or minus one standard deviation from the mean on the Short Form Test of Academic Aptitude, a group test of abstract reasoning and intellectual development (CTB--McGraw-Hill, Del Monte Research Park, Monterey, California). Subject characteristics are presented in Table 1.

Materials

The items to be remembered were consonant trigrams. No letters were repeated within a trigram. No more than one letter was repeated in consecutive trigrams and this repeated letter never appeared in the same letter position. The trigrams were selected from the Scott and Baddeley (1969) norms and were of moderate-to-high within-trigram acoustic similarity, ranging from 0.20 to 0.38, and of moderate-to-high association value, ranging from 0.58 to 0.75. See Appendix C for lists of trigrams and their respective values. The trigrams were presented in a fixed random order to all children. The items for the interpolated tasks were single digits (Healy, 1974; Lindley, 1963; Loess & McBurney, 1965; Peterson, 1969).

All items were displayed on a 20.3 cm x 25.4 cm black and white television screen, positioned approximately 40 cm from a child's eyes. The television was operated by an Apple II microcomputer (Apple Computer Corporation, 10260 Bandley Drive, Cupertino, California) or a TRS-80 microcomputer (Tandy Corporation, One Tandy Center, Fort Worth,

Table 1

Mean Subject Characteristics Within and
Across Encoding Strategy Conditions

Learning Disabled Children				
	Chronological Age (yrs)	Intelligence Quotient	Reading* Grade Level	Math* Grade Level
Control Condition	10.0	96.8	-2.9	-1.2
Vocalization Condition	10.0	98.5	-3.1	-1.4
Elaboration Condition	10.2	95.6	-2.7	-1.8
Total	10.1	97.0	-2.9	-1.3
Normal Children				
Control Condition	10.5	103.1	+0.8	+0.9
Vocalization Condition	10.3	102.0	+0.9	+1.0
Elaboration Condition	10.5	105.8	+0.9	+0.9
Total	10.5	103.6	+0.8	+0.9

*Minus scores indicate years behind grade level; plus scores indicate years above grade level.

Texas). All children were individually tested in one room of a mobile laboratory parked at each school.

Procedure

Each child received 24 trials on each of two days. A trial was defined as a ready signal of 2-sec duration, a to-be-remembered consonant trigram presented for 6 sec, a variable-length retention interval, and a recall cue of 10-sec duration. A ready signal consisted of two asterisks presented on the television screen and the recall cue was three question marks. Half of the trials on each day included retention intervals filled with a series of single digits of .6-sec duration each. The inter-digit interval was .065 sec. The time between offset of the trigram and onset of the first digit of the filled trials or the comparable period of the unfilled trials was .6 sec. As each digit was presented, it was to be said aloud. The other half were blank, unfilled trials. Children in each group received the 12 filled trials either before or after the 12 unfilled trials on a random basis. Those who received the filled trials first on Day 1, received the unfilled trials first on Day 2, and vice versa.

The retention intervals were 0, 3.3, 5.9, 11.9, 18.6, and 30.5 sec, as a result of offset-onset time, digit durations, and inter-digit intervals (hereafter for simplicity to be referred to as 0, 3, 6, 12, 18, and 30 sec, respectively). The intertrial interval was 8 sec. Each retention interval was tested once in each block of six trials. Each retention interval preceded every other retention interval an approximately equal number of times (Turvey, Brick, & Osborn, 1970a, 1970b). All children were instructed to orally recall the letters of each trigram in the order of presentation from left to right and to guess when uncertain.

Separate sub-groups of normal and LD children were instructed in one of three encoding strategies to be used during the 6 sec presentation interval. Children in the Control condition were instructed only to "study" the consonant trigram during its presentation. Those in the Vocalization condition were instructed to "say the letters out loud twice" at a rate of approximately one letter per sec. Children in the Elaboration condition were instructed to vocalize any words which began with the consonants in the trigram and which were conceptually related, in the order presented. For example, if the to-be-remembered item was CDL, a child might have said "child-dad-love." Children selected a prize from various toys and games at the end of each day's session for "doing well." At the conclusion of the second day's session, children were asked if they did anything during either the presentation interval or the retention interval to help them remember the items. See Appendix B for task instructions and post-experimental questions.

Before the trials began, all children were pretested to ensure that they knew the letters of the alphabet and the digits zero through nine. Then they practiced no less than five trials of trigram recall after various retention intervals with no interpolated activity. Included in this practice was training on the appropriate encoding strategy. Next they practiced reading aloud no less than five series of digits of different lengths with no memory requirement. Finally they practiced no less than five trials of trigram recall after variable-length, filled, retention intervals. Children practiced until they were responding appropriately, had no questions, and appeared comfortable with the sequence of events.

Experimental Design

Two between-subjects variables were Groups (Normal/LD children) and Encoding Strategy. Two within-subjects variables were Type of Retention Interval and Length of Retention Interval. The overall design was a 2 x 3 x 2 x 6 mixed multivariate analysis of variance. There were 12 children in each between-subjects condition.

Results

The main dependent variables were the proportion of consonants correctly recalled regardless of order and the proportion of consonants recalled in their correct positions. Since the outcomes were similar for both variables in all analyses, only those for correct recall regardless of order are reported. See Tables 1, 2, and 3, Appendix A, for complete summaries of the analyses of variance. The mean proportions of consonants recalled across retention intervals revealed no substantive forgetting for either group when the intervals were unfilled (LD = .99, .99, .99, .98, .99, .97; normal = .99, .99, .99, .99, .99, .99 for 0, 3, 6, 12, 18, 30 sec, respectively). Since there was no substantial variability, these data were not included in any subsequent analyses. A three-way factorial mixed multivariate analysis of variance was conducted on recall after filled retention intervals (Hummel & Sligo, 1971). See Table 1, Appendix A, for a summary of the analysis. Based on these findings, Lindquist Type III (Lindquist, 1953) univariate analyses of variance were conducted. See Tables 2 and 3, Appendix A for the summaries of these analyses.

Overall, LD children recalled significantly fewer consonants (mean = .72) than normal children (mean = .84),

$F(2, 130) = 17.76$, $p < .001$, multivariate; $F(1, 66) = 38.74$, $p < .001$, univariate.

Collapsed across groups and retention intervals, there were no significant differences in recall among encoding strategies, $F(4, 130) = 1.74$, $p < .14$, multivariate; $F(2, 66) = 3.62$, $p < .03$, univariate.

Collapsed across groups and encoding strategies, significant forgetting across retention intervals obtained, $F(10, 658) = 43.45$, $p < .001$, multivariate; $F(5, 330) = 104.30$, $p < .001$, univariate.

Collapsed across retention intervals, the encoding strategies did not have significantly different effects on the recall of normal and LD children, $F(4, 130) = .99$, $p < .59$, multivariate; $F(2, 66) = .60$, $p < .56$, univariate.

Collapsed across encoding strategies, LD children's forgetting across retention intervals differed significantly from that of normal children, $F(10, 658) = 2.45$, $p < .007$, multivariate; $F(5, 330) = 4.30$, $p < .001$, univariate. Comparisons of recall between retention intervals within groups with t tests are presented in Table 2. Comparisons of recall at each retention interval between groups produced t scores of .55, 1.10, 2.79 ($p < .005$), 4.48 ($p < .0005$), 2.94 ($p < .005$), and 3.66 ($p < .0005$) for retention intervals of 0, 3, 6, 12, 18, and 30 sec, respectively. Important findings for the interaction are: significant forgetting between 0 and 3 sec for LD children but not for normal

Table 2

Normal and Learning Disabled Within-Subjects t Tests Between Retention Intervals (RI)

Learning Disabled Children						
Retention Interval						
RI	0	3	6	12	18	30
0		2.07[c]	6.56[c]	11.34[c]	13.48[c]	14.12[c]
3			4.49[c]	9.27[c]	11.41[c]	12.06[c]
6				4.78[c]	6.92[c]	7.56[c]
12					2.14[a]	2.78[b]
18						.64
30						

Normal Children						
Retention Interval						
RI	0	3	6	12	18	30
0		1.28	3.35[b]	5.92[c]	10.06[c]	9.84[c]
3			2.07[a]	4.64[c]	8.77[c]	8.56[c]
6				3.80[c]	6.71[c]	6.49[c]
12					4.14[c]	3.92[c]
18						.21
30						

[a] $p < .025$

[b] $p < .005$

[c] $p < .0005$

children, equivalent recall between normal and LD children at 0 and 3 sec but significantly worse recall for LD children thereafter, and larger differences in recall between normal and LD children at 6 sec than at 3 sec, and at 12 sec than at 6 sec. At 18 sec there was a smaller difference in recall between normal and LD children than at 12 sec, indicating that LD children reached their asymptotic levels of recall sooner than normal children. The mean proportions of correct recall are presented graphically in Figure 2.

The significantly faster rate of forgetting and lower asymptotic level of recall for LD children are also in evidence in Figure 3. These curves include data from only those children who had perfect recall at 0 sec.

The probabilities of correct recall from primary memory are .95, .81, .51, .19 for all LD children and 1.0, .87, .67, and .41 for all normal children after 0, 3, 6, and 12 sec retention intervals, respectively. These probabilities were estimated using the Kintsch et al. (1971) variation of the Waugh and Norman (1965) formula:

$$p(PM_i) = \frac{p(R_i) - p(SM)}{1 - p(SM)}$$

where $p(PM_i)$ denotes the probability of recalling an item from primary memory after i intervening events (i.e., interpolated digits), $p(R_i)$ denotes the probability of recalling an item correctly after i events, and p 'M) denotes the

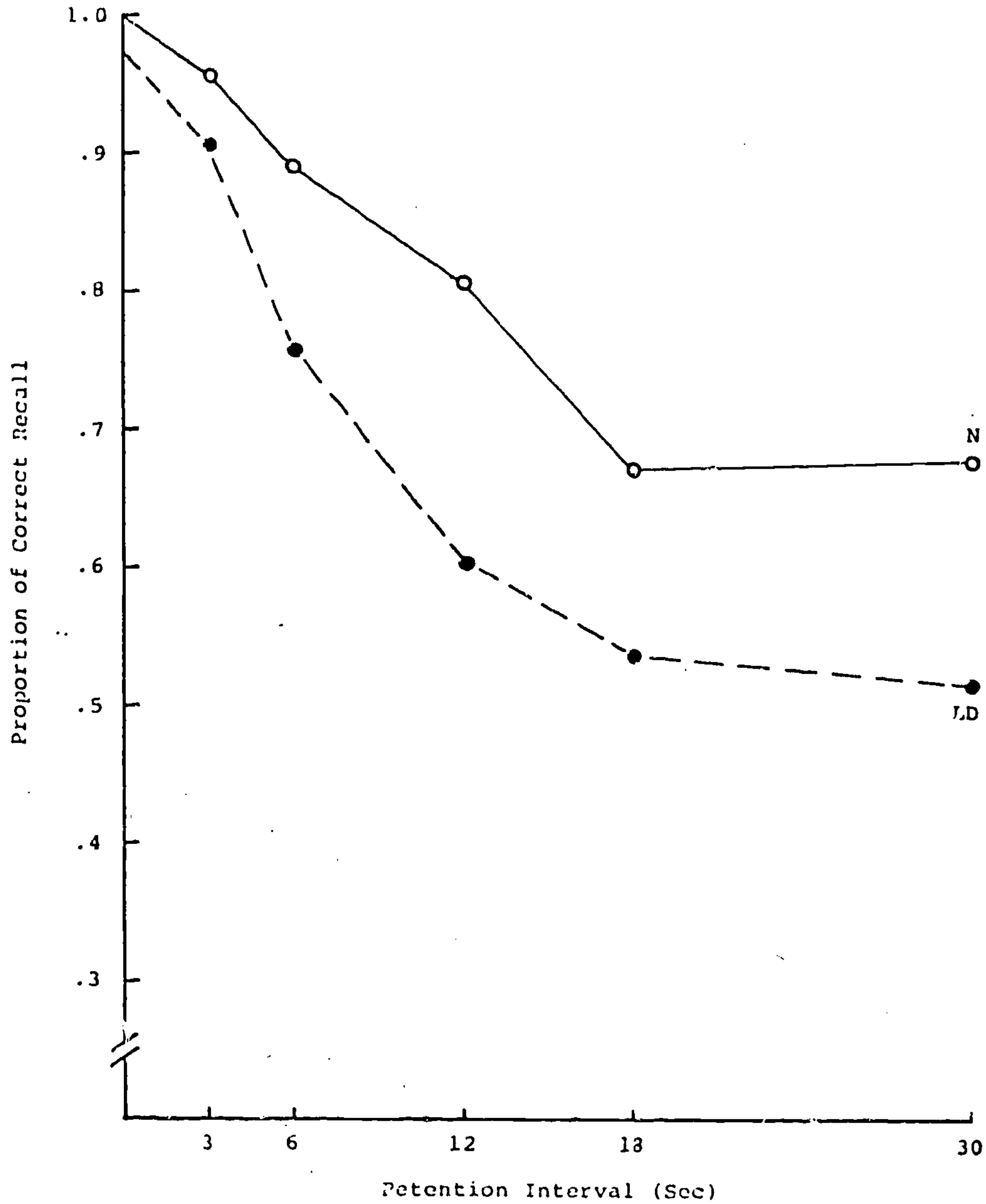

Figure 2. Proportion of consonants correctly recalled as a function of retention interval by normal (N) and learning disabled (LD) children.

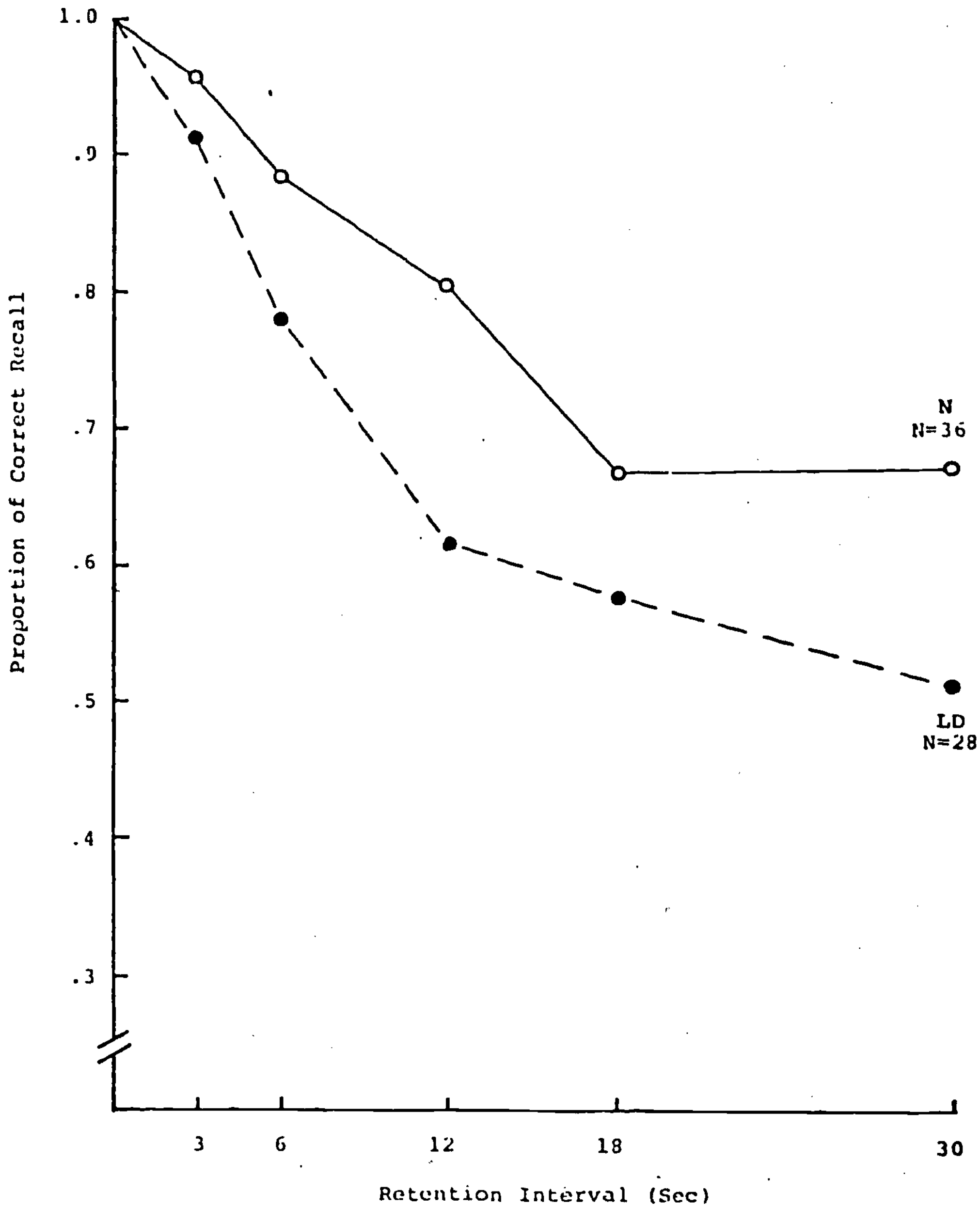

Figure 3. Proportion of consonants correctly recalled as a function of retention interval by normal (N) and learning disabled (LD) children who had perfect recall at 0 sec.

probability of recalling an item correctly from secondary memory (estimated from performance at the longest retention interval). Crowder (1976) has shown that the Waugh and Norman formula provides convergence on estimates obtained from other methods, despite differing theoretical assumptions.

Collapsed across groups, significantly different effects of the different encoding strategies across retention intervals obtained, $F(20, 658) = 1.55$, $p < .058$, multivariate; $F(10, 330) = 2.48$, $p < .007$, univariate. The mean proportions of correct recall are presented graphically in Figure 4. It can be seen that the interaction was primarily due to greater forgetting with the Vocalization strategy than with the Control condition and the Elaboration strategy between 6 sec and 18 sec.

The different encoding strategies affected recall across retention intervals differently for normal than for LD children, $F(20, 658) = 1.74$, $p < .023$, multivariate; $F(10, 330) = 1.80$, $p < .059$, univariate. Comparisons of recall between encoding strategies at each retention interval for both groups were conducted with t tests. The interaction was primarily due to significantly lower recall by LD children using the Vocalization strategy than LD children in the Control condition at 12 sec ($t(66) = 2.07$, $p < .025$) and 30 sec ($t(66) = 1.73$, $p < .05$) and significantly lower recall by normal children using the Vocalization strategy

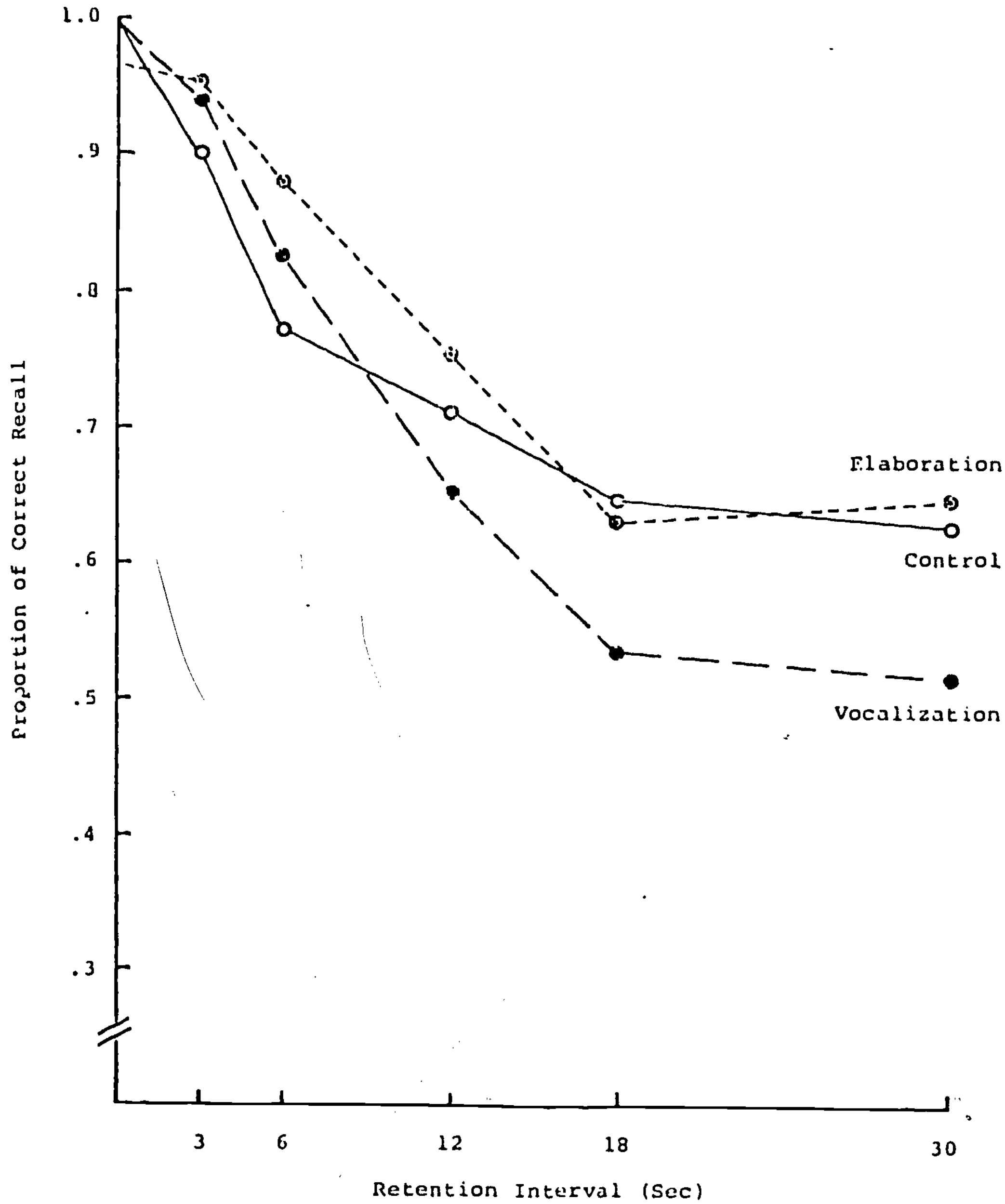

Figure 4. Proportion of consonants correctly recalled as a function of retention interval and encoding strategy.

than normal children in the Control condition at 18 sec ($t(66) = 2.08$ $p < .025$). The mean proportions of consonants recalled for normal and LD children are presented graphically in Figures 5a and 5b, respectively. In comparing the curves of normal and LD children on any single strategy, the faster rate of forgetting and lower level of final recall for LD children are also in evidence.

To monitor performance on the interpolated task, the number of digit errors (mispronunciations and omissions) during the filled intervals also was recorded (Crowder, 1967a, 1967b). A two-way analysis of variance (Groups by Encoding Strategies) revealed that LD children made significantly more digit errors (mean = 23.28) than normal children (mean = 10.42), $F(1, 66) = 12.80$, $p < .005$. There were no reliable differences between encoding strategies, $F(2, 66) = 3.00$, $p < .10$ and a nonsignificant interaction, $F(2, 66) = 1.36$, $p < .10$. See Table 6, Appendix A, for a summary of the analysis.

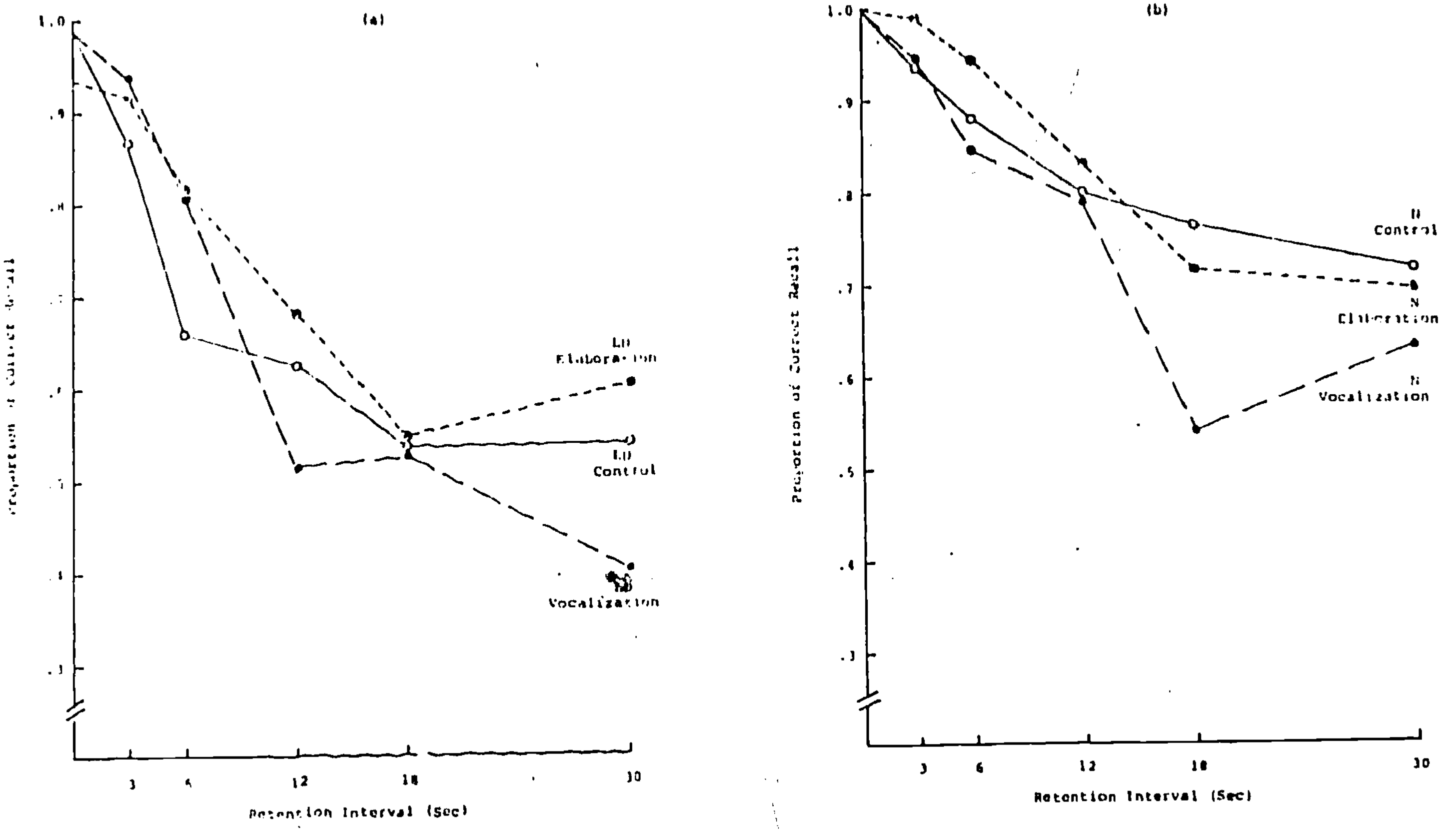

Figure 5. Proportion of consonants correctly recalled as a function of retention interval and encoding strategy by learning disabled (LD) and normal (N) children.

Discussion

Unfilled Retention Intervals and Cognitive Strategies

One of the most important findings of the present study was the lack of any forgetting across unfilled retention intervals by LD children. While the relative paucity of research in this area and the limitations in the available research led to only tentative predictions, if LD children were deficient in rehearsal strategies, it was expected that significant forgetting would occur (Bauer, 1977b). The minimally sufficient strategies to perform well on the unfilled-interval task would be classified as of the maintenance or non-elaborative type (Craik & Watkins, 1973; Rundus, 1977). LD children were at the least employing these types of strategies. Supportive evidence for this comes both from behavioral evidence and post-experimental subjective reports. Upon questioning, every LD child reported active strategy usage and behavioral observations (i.e., lip movements, whispering, vocalizing; Flavell et al., 1966) of such use were recorded for 25 of the 36 LD children, including all 12 children in the uninstructed Control condition. Contrary to expectations, it is concluded that LD children were at the least actively involved in maintaining the information.

In the only other studies employing filled and unfilled retention intervals (Bauer, 1977a, 1977b), significant forgetting across unfilled intervals obtained for LD children. Bauer took this as strong evidence for a deficiency in rehearsal. It is possible that longer presentation durations (6 sec) in the present study than in Bauer's (3 sec) contributed to the different findings. However, some evidence suggests that this was not the case. Four LD children in the present study were given an additional 12 trials of recall after unfilled retention intervals with presentation durations shorter or equal to that used by Bauer (one child at 2 sec, three children at 3 sec). These were administered after the main testing. Mean proportion of correct recall (.97) did not differ markedly from that with 6 sec presentation duration (.99).

The inconsistencies in Bauer's studies have already been highlighted and are reason to view his results with caution. These include further decrements in recall with filled retention intervals indicating the presence of rehearsal, recency effects comparable to normal children's for 6- and 9-word lists after an unfilled retention interval, indicating rehearsal, and comparable primacy effects for 12-word lists indicating rehearsal.

Differential Forgetting after Filled Retention Intervals

Another important finding of the present study was LD children's greater rate of forgetting and lower asymptotic level of recall than that of normal children, as seen in Figure 2. These reflect a more rapidly declining contribution of information from primary memory and less transfer into or retrieval from secondary memory (Atkinson & Shiffrin, 1968; Glanzer, 1972; Shiffrin, 1976). Under the assumption that acquisition is equivalent when recall is perfect at 0 sec, the inferior primary and secondary memory components of LD children are also in evidence in Figure 3. This observation remains when comparing both groups on the individual encoding strategies in Figures 5a and 5b. It is known that recall can be increased by sacrificing performance on the interpolated task (Crowder, 1967a, 1967b). That the half of the normal children who performed best on the digit-naming task did not recall less than the half who performed worst (.84 and .83, respectively) indicates that this potential trade-off was not responsible.

To obtain a better estimate of the number of LD children exhibiting inferior primary and secondary memory, they were ranked according to overall mean proportion of consonants recalled. When LD children were divided into low-, medium-, and high-performing sub-groups, less than one-third (n = 11, mean = .82) performed as well as the normal children as a whole. When recall of this high-performing subgroup is plotted across retention intervals, as seen in Figure 6, their forgetting function is nearly identical to that of the normal children. The remaining sub-groups

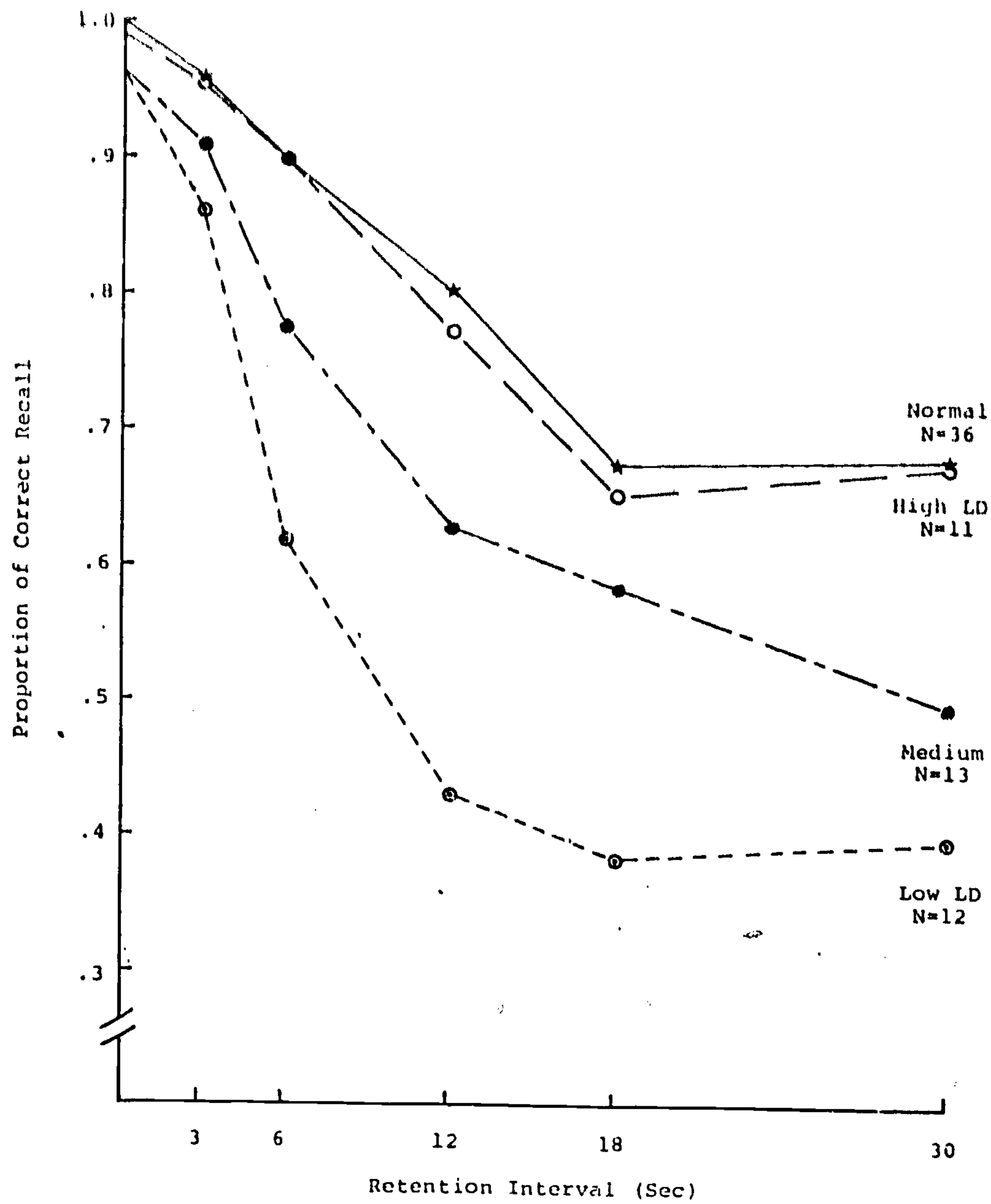

Figure 6. Proportion of consonants correctly recalled as a function of retention interval, with learning disabled (LD) children divided on total recall.

display progressively faster rates of decline and lower asymptotes. On the basis of these findings, it is apparent that not all children classified as learning disabled experience problems in retaining information. However, as Figure 6 shows, a large proportion of them do.

Although there were minimal differences between groups on the indices of intellectual level, it would be important to show that the performance differences were not related to these IQ differences. Evidence to this effect can be seen by dividing groups into high and low IQ subgroups and comparing their recall across retention intervals. The overall mean proportions of consonants recalled were .80 for the high IQ normal sub-group (mean IQ = 108.2), .77 for the low IQ normal sub-group (mean IQ = 98.5), .70 for the high IQ LD sub-group (mean IQ = 103.4), and .74 for the low IQ LD sub-group (mean IQ = 89.8). The mean proportions of correct recall as a function of retention intervals are represented graphically in Figure 7. The recall differences between high and low IQ normal children and between high and low IQ LD children are minimal and do not appear to be related to intellectual level in any systematic manner. Further discussion of the inferior memory performance of LD children will be deferred until the encoding strategies have been covered.

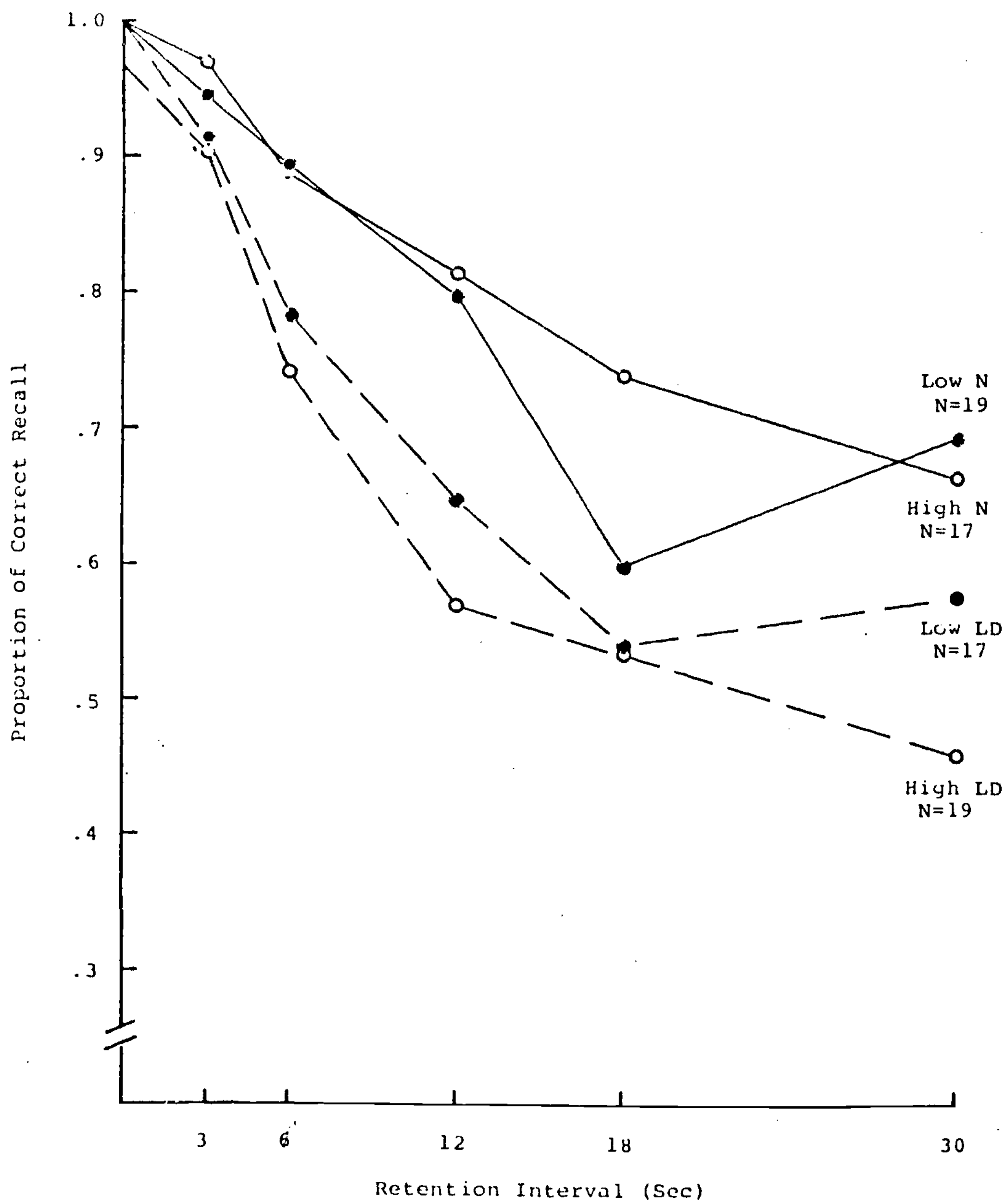

Figure 7. Proportion of consonants correctly recalled as a function of retention interval, with normal (N) and learning disabled (LD) children divided on IQ.

The Effects of Encoding Strategies

The effects of the encoding strategies were relatively the same for normal and LD children (although these effects took place at different absolute levels of recall): minimal differences between the uninstructed Control condition and the Elaboration strategy, and a suppressive effect of the Vocalization strategy. The main difference between groups was the retention interval at which the Vocalization strategy had its most pronounced suppressive effect. Previous research has shown that ordered vocalization of the to-be-remembered items has a short-lived facilitative effect when (a) compared to a suppressive vocalization strategy (Kintsch et al., 1971; Tell, 1971, 1972), (b) compared to a silent reading strategy (Tell & Ferguson, 1974; Tell & Voss, 1970), and (c) compared to an uninstructed condition in subjects with strategy deficiencies (Ellis, 1970). Item vocalization has been found to have a detrimental effect on recall when compared to an uninstructed condition in subjects utilizing cognitive strategies. The basis of this effect is held to be interference with a subject's own, more efficient, mode of information processing (Conrad & Hull, 1968; Crowder, 1970; Ellis, 1969; Glanzer & Meinzer, 1967; Hagen & Kingsley, 1968; Hagen, Meacham, & Mesibov, 1970; McCarver & Ellis, 1972; Routh, 1970; Wheeler & Dusek, 1973). Based on the finding with unfilled retention intervals, that LD children were actively engaged in encoding strategies, the suppressive effect of the Vocalization strategy is understandable.

If children are utilizing efficient cognitive strategies, then the provision of a comparable one should result in no substantial elevation in performance. That the Elaboration strategy resulted in performance not substantially different from the uninstructed Control condition but superior to the Vocalization strategy adds further support to the contention that LD children were employing active intake strategies. Of the studies using inferential indices of rehearsal, Marshall et al. (1976) found no support for the hypothesis of a rehearsal deficit in LD children. Included in Bauer's (1977a, 1977b) results was evidence of rehearsal for LD children, although not as efficient as that of normal children. Spring and Capps (1974) also found evidence of not-as-efficient rehearsal in LD children. Of the studies using a direct instructional approach, Bryan (1972) and Tarver et al. (1976) obtained no differences between encoding strategies with LD children. Torgesen (1977a) obtained facilitation on a free recall organizational strategy but no significant differential improvement with a serial recall cumulative rehearsal strategy in LD children. Torgesen and Goldman (1977) found strategy training to significantly improve LD children's recall. All of these studies have previously been shown to suffer from various problems. Consequently, their conclusions must be viewed as tentative.

Memory Deficiencies and the Underlying Processes

The present and previous research indicates the influence of some variable, or variables, which affects recall from both the primary and secondary memory components, regardless of the encoding strategies used by LD children. It is hypothesized that a large proportion of those children who score in the normal range of intellectual functioning but who experience problems in learning are characterized by slower verbal processing of information and greater interference than their normally-achieving peers. A slower rate of information processing and greater interference would result in less efficiency in the use of strategies to maintain information in primary memory (e.g., repetition) and in the use of strategies to transfer information to and retrieve information from secondary memory (e.g., elaboration, search).

Rate of information processing. A direct measure of slower information processing in the present study is performance on the digit-naming interpolated task. At a presentation rate of .6 sec per digit, LD children made a significantly greater number of naming errors than normal children. This interpretation gains support from the findings of Spring and Capps (1974) and Spring (1976) that LD children were significantly slower than normal children in the speech-motor encoding of digits, colors, and pictures, with the largest difference on digit naming. Rugel's (1974) re-analysis of 25 studies reporting WISC-R scores for LD children also corroborates this position. He found LD children were inferior to normal children only in the Sequential category, including Digit Span and Coding subtests. Digit Span can be considered a measure of the speed of transfer to secondary memory (Craik, 1971; Glanzer, 1972), and Coding is a task in which rate of information processing is critical (Royer, 1971). From another line of research, Vellutino, Smith, Steger, and Kaman (1975) and Vellutino, Steger, and Kandel (1972), using letter-naming tasks, found that "poor readers were generally less effective than the normals in rapidly transforming the visual material into a verbal code" (Vellutino et al., 1975, p. 492). Anecdotal evidence of slower rate of processing in the present study was the observation that LD children repeatedly took longer to produce an answer in their 10 sec recall interval.

The speed with which various functions of information processing are conducted, termed "Cognitive Speed" by Carroll and Maxwell (1979), is a basic component, whether explicitly stated or implied, in many contemporary models of memory (e.g., Atkinson & Shiffrin, 1971; Bjork, 1975; Craik & Jacoby, 1975). The proportion of information that can be maintained by repetition in primary memory is an inverse function of the time between repetitions. To be transferred successfully to secondary memory, items must be maintained in primary memory sufficiently long to permit completion of coding processes (Shiffrin, 1975). There is also a higher probability of some information being transferred as the number of repetitions increases (Brelsford & Atkinson, 1968; Dark & Loftus, 1976; Rundus, 1971). Consequently, if LD children are slower in the speed with which items enter the rehearsal/coding operation, are maintained, or are encoded, there is a higher probability that some information will be lost before it can be cycled, resulting in inferior primary memory, and a higher probability that less information will be transferred, resulting in inferior secondary memory, across encoding strategies.

For information that is in primary memory or that has been successfully transferred, the speed of various retrieval subprocesses also bears significantly on the accuracy of recall. Retrieval from secondary memory has been characterized as a loop consisting of (a) a search through various subsets of information in secondary memory, (b) recovery to primary memory of what has been found, and (c) a decision whether to emit a response or continue the search (Shiffrin & Atkinson, 1969). Retrieval from primary memory involves search and decision making. With a finite recall interval, the slower the search, the slower the recovery, or the slower the decision making, the higher the probability of giving an incorrect response (Shiffrin, 1976). While LD children do not differ from normal children on order-of-output strategies (Bauer, 1977a; Marshall et al., 1976), if they differ in the speed of retrieval processes, decrements in primary and secondary memory rformance would be expected, irrespective of most encoding strategies.

Susceptibility to interference. Evidence of the differential effect of one type of interference in the present study can be seen by comparing recall of normal and LD children on their trial-one recall and on recall on all other (23) trials with filled retention intervals. It has been shown that recall on the Brown-Peterson task is strongly affected by proactive interference of previous trials (Keppel & Underwood, 1962; Loess, 1964; Loess & Waugh, 1967). On the first trial, proactive interference effects are at a minimum. Mean proportion of correct recall on trial one and on the remaining trials was .92 and .83 for normal children, respec y, and .87 and .71 for LD children, respectively; a larger decrease for the LD children as a function of trials. One direct investigation of proactive interference effects in LD children was performed by Leslie (1975). She presented six items in a spatial array and children were to reconstruct the sequence. The same items were used in different orders on the first six trials; on the seventh trial a new set of items was presented. Normal and LD children's recall were comparable on trial one, but thereafter that of the LD children deteriorated more rapidly. On trial seven both groups' recall improved such that no differences remained between them. An interesting implication of these findings is that LD children may not forget, differentiate, or terminate processing the acquired items as well as normal children. In this light, while Torgesen (1977a) failed to obtain significant improvement by training LD children on a serial recall rehearsal strategy, this did obtain by training on a free recall conceptual organization strategy--a strategy which served to differentiate items in a list and possibly reduce their interference.

While the processes that underlie proactive interference have been a source of much debate and investigation in recent years (Postman, 1975), the strongest studies support the position that the effect results from a combination of inefficiency in transferring information to secondary memory, particularly on early trials, and inefficiency in retrieving information from secondary memory, with emphasis on later trials (Chechile & Butler, 1975; Ellis, 1977, O'Neill, Sutcliffe, & Tulving, 1976). Transfer failure occurs because of the continued presence in primary memory of similar items from the previous trial, due to a subject still in the process of recalling or thinking about them. During the presentation interval, due to this increased load on primary memory capacity and the increased difficulty in differentiating the current trial's to-be-remembered items, some items are not processed efficiently and thus are not transferred. Retrieval failure from secondary memory occurs because of the increasing number of items in the set of transferred items, the limited time to complete the search, and the finer temporal discriminations upon which the search must be based (Baddeley, 1976; Shiffrin & Atkinson, 1969). Recall failure from primary memory occurs because of the increased noise in the system as a result of the presence of previous items (Shiffrin, 1976; Shiffrin & Cook, 1978). Consequently, if the effects of proactive interference are greater for LD children, they should serve to suppress recall from both primary and secondary memory and across encoding strategies.

It is also possible that LD children experience greater retroactive interference effects of the interpolated task than normal children. Recall on the Brown-Peterson task is strongly influenced by variations in interpolated activity (Corman & Wickens, 1968; Dillon & Reid, 1969; Posner & Rossman, 1965; Wickelgren, 1965). If LD children were deficient in cognitive strategies, the interpolated task would be expected to reduce their recall less from the level of recall after unfilled retention intervals than normal children, who employ mnemonic strategies. However, LD children's recall after filled retention intervals deteriorated <u>more</u> than that of normal children. Not only does this provide additional support for the contention that LD children are strategically active, but, since the decrement in recall after filled retention intervals did not equal that of the normal children, it also suggests greater interfering effects of the interpolated task for LD children. Casual observation suggested that committing errors on the digit-naming task produced greater interference than correct naming. With a greater number of interpolated task errors, LD children would also have suffered greater retroactive interference as a result. Davis and Bray (1975) conducted an investigation on bisensory memory which adds support to the contention that reading disabled children experience greater interference than normal children.

It is generally agreed that the basis of the interference of the interpolated activity is a combination of rehearsal distraction, resulting in more difficult maintenance or transfer of the to-be-remembered items, and of retrieval competition, due to an increasing set of similar items from which the to-be-remembered items are to be selected (Crowder, 1976). Since maintaining items in primary memory and transferring items to secondary memory both require a large portion of a person's limited processing capacity (Kahneman, 1973), additional demands of an interpolated task exert their influence over both memory components (Turvey & Weeks, 1975). Consequently, if

LD children suffer greater retroactive interference, these effects should be in evidence on recall from both primary and secondary memory.

Alternative accounts. It has been shown that most of the studies that have found LD children to be inferior to normal children in primary and secondary memory, have given emphasis to the secondary memory deficit, and have invoked deficient rehearsal strategies as an explanation. This also describes a recent study by Cohen and Netley (1978), except they interpret their data as an indication of a "much less flexible processing system" in which "overloading causes a breakdown" (p. 633). However, this explanation is circular, with no evidence of inflexibility other than inferior recall.

The hypothesis that LD children are characterized by a slower rate of information processing and greater susceptibility to interference can account for both the findings that have been stressed and those that have been ignored in these other studies and provide directions for future investigations. It has previously been shown how performance can appear to result from deficient rehearsal strategies, particularly in studies using inferential indices of rehearsal, as a result of the effects of slower transfer and retrieval processes and greater interference. The effects of these processes can also have the appearance of "overloading." Primary memory is considered to have a large (but finite) momentary capacity and a smaller maintenance capacity (Shiffrin, 1975). This maintenance capacity is determined by the number of items receiving the required rehearsals in a specified interval of time. Thus, the faster the rate of processing the greater the maintenance capacity. Also, the more that items receive the required attention, the higher the probability that they will be transferred, resulting in more available space in primary memory. The larger the number of similar items unattended in primary memory, the higher the probability for errors due to interference (Shiffrin, 1976). Consequently, when normal and LD children are presented the same amount of information, it is more likely due to the proposed processes that LD children's maintenance capacity will be "exceeded" and rapid forgetting will occur.

Possible Explanations of Process Differences

Speculations on the basis for the slower rate of processing and greater interference of LD children follow. It is possible that these are structural limitations of the system. Atkinson and Shiffrin (1968) included invariant processes as part of the structural features in their original formulation. This is the least preferred explanation. Before it could be accepted with any confidence, attempts to modify these processes with all the available training procedures would have to have failed (Brown, 1974).

It is possible that there is a developmental lag in these processes in LD children. Haith (1971) and Chi (1977) found faster rates of processing visual information in older subjects. Spring (1976) and Spring and Capps (1974) found the rate of speech-motor encoding to be a function of age. And Belmont and Butterfield (1971) observed that retrieval processes were more rapid in older subjects.

Another explanation is that LD children engage in tasks utilizing these processes less than normal children and consequently experience less practice in their operation (Spring, 1976; Spring & Capps, 1974). Bearing on this, Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977) describe the difference between "controlled" and "automatic" processes and show that, with repeated experience, processes become more automatic. As a result, they are faster and do not stress capacity limitations. LD children may be characterized by fewer processes that are automatic.

It is possible that the primary difference between normal and LD children is the rate of processing, and that greater susceptibility to interference is derived from this. As stated above, if items are maintained less efficiently, if items are transferred more slowly, if subsets are searched more slowly, the probability for interference effects to occur would be greater.

Educational Implications

There is a vital relationship between research on memory processes and improvement in educational practice The efficacy of any instructional effort is, in large part, a function of the same components of memory that are investigated in the laboratory. wever, before practice can be tailored from rese .nowledge, a reasonably consistent data base needs to be established. As discussed previously, there is a paucity of available investigations of memory in LD children and many of these suffer from methodological limitations. If the conclusions of the present study and a few others are elaborated in subsequent investigations, a foundation for the development of applied techniques with LD children would exist. Some of the implications of the available information will be discussed.

Since there is a variety of support for the contention that LD children are as mnemonically active as normal children, teachers would not be concerned with the remediation of deficiencies in primary (short-term) or secondary (long-term) memory per se. However, the performance of over two-thirds of the LD children in the present study reflected faster loss of information from primary memory and less transfer into or retrieval from secondary information. Evidence has been presented that these are results of a slower rate of information processing and its concomitant effects. Therefore, teachers should first be sensitive to evidence indicating which students do and do not experience memory problems. For those who do, there are two broad categories of instructional techniques which can be adopted: those which take into account this slower rate of processing and those which attempt to remediate it.

When presenting new information to LD children, such as a history lesson or the steps of a mathematical computation, a teacher should proceed at a pace which would allow the students' slower (but otherwise presumably adequate) cognitive strategies to operate. Periodic monitoring, in the form of questions, would provide a teacher feedback on the appropriateness of the particular pace. Situations in which large amounts of information are presented at one time should be avoided. Particularly when a great deal of material is presented orally, as in a social studies lesson, there is a real possibility that the slower rate of information processing and, consequently, the inferior maintenance of information in primary memory of the LD children would be revealed. Over time, the reduced transfer of information to secondary memory would become pronounced. At testing, ample time for retrieving the necessary information should be provided, unless of course speed of processing is being assessed.

Teachers could encourage or directly train acquisition and retrieval strategies which can be quickly executed. Strategies which reduce both the amount of information to be retained (and therefore the load on primary memory) and the amount of interference would reduce the necessity for extremely quick maintenance or transfer processing. Children could be trained to organize the material into familiar categories and chunking it into manageable units (e.g., three or four bits). As an alternative, the teacher could organize the material at presentation into categories or chunks that might be easily perceived by the children or that would facilitate quicker use of the children's strategies. Temporal grouping has been found to improve retention of order information more than item information, and thus would be useful in such tasks as learning the names of the Presidents or spelling. Task strategies which involve saying aloud the material to be acquired should be avoided because of the potentially deleterious consequences on a student's memory. This is particularly relevant for sequential information, such as a set of instructions or the letters of a word.

A variable too easily overlooked in instructional efforts is the use of extensive amounts of practice. As discussed previously, cognitive processes which are repeatedly employed become faster in their execution and place less stress on an individual's information processing capacity. The teacher could provide extensive experience with a variety of tasks requiring use of the same strategies.

Children could be actively encouraged to employ the strategies with increasing speed. The teacher could overtly model the appropriate strategy and gradually quicken her pace. When appropriate to the task, vivid pictures or taped elaborations of the material could be presented. Practice should be provided in maintaining the necessary information in primary memory, in transferring it to secondary memory, and in retrieving it. And before each lesson, children could be reminded of the importance of these techniques for successful performance.

In essence, the educational import of some of the investigations of memory processes with LD children is that a teacher's success in maximizing a student's performance is, in large part, a function of her ability to: (a) analyze educational tasks in terms of the demands they place on memory and the type of acquisition they require, (b) based on the preceding analysis, train the appropriate techniques to remediate, or structure the material in appropriate ways to take into account, the LD children's slower rate of information processing, and (c) provide extensive experience with the relevant tasks and techniques.

Future Investigations

A number of studies are suggested by the present contention of a slower rate of information processing in LD children. To compare the speed and efficiency of rehearsal, normal and LD children could be required to engage in a concurrent activity during the <u>presentation</u> of items to be free recalled (Peterson, 1969; Silverstein & Glanzer, 1971). If LD children are less able to handle the demands on capacity, then their recall should suffer a greater decrement over a condition with no competing activity. To study the speed of processing at presentation and to reduce the effects of potential retrieval differences, normal and LD children could be compared on recognition memory tasks with varying presentation rates (Brown, 1974; Ellis, McCartney, Ferretti, & Cavalier, 1977). The Brown-Peterson task could be employed with varying levels of interpolated task difficulty and similarity (Corman & Wickens, 1968; Dillon & Reid, 1969). If LD children suffer greater interference effects, they should be more adversely affected by increased difficulty and similarity. To determine whether LD children do not differentiate or terminate processing information that is no longer relevant as well as normal children, a comparison on directed forgetting would be revealing (Bjork, 1972; Bray, 1979). A more precise analysis of encoding and retrieval processes and their interrelationship would be obtained by employing a serial probe task with pause time and response latency measures (Belmont & Butterfield, 1971; Butterfield et al., 1973). Following these studies, investigations of the applied implications should be conducted.

Summary

Previous investigations of memory processes in LD children were reviewed, and inconsistencies and methodological limitations were identified in the majority of them. The present study found no support for the contention that LD children are deficient in rehearsal strategies, per se. Both primary and secondary memory processes were found to be inferior to those of normally-achieving peers. Evidence pointed to the operation of some processes that would serve to attenuate the level of recall from both memory components across the effects of most encoding strategies. It was argued that many LD children are characterized by a slower rate of verbal information processing and greater susceptibility to interference effects than normal children.

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APPENDICES

Appendix A

Summaries of Analyses of Variance

Table 1

Proportion of Correct Responses Regardless of Order and Proportion of Correct Responses in the Correct Positions After Filled Retention Intervals

Summary of Multivariate Analysis of Variance

Source	Wilks Lambda	*F*	df	*p*
Groups (G)	.617	17.76	2/130	.001
Encoding Strategies (E)	.901	1.74	4 [illegible] 0	.144
Retention Intervals (R)	.363	43.45	10/658	.001
G x E	.942	.99	4/130	.585
G x R	.929	2.45	10/658	.007
E x R	.912	1.56	20/658	.058
G x E x R	.902	1.74	20/658	.023

Table 2

Proportion of Correct Responses Regardless of Order After Filled Retention Intervals

Summary of Univariate Analysis of Variance

Source	SS	df	MS	F	p
Groups (G)	216.750	1	216.750	38.74	.001
Encoding Strategies (E)	40.505	2	20.252	3.62	.031
G x E	6.681	2	3.340	.60	.558
Error	369.250	66	5.595		
Retention Intervals (R)	1,422.463		284.493	104.30	.001
G x R	58.695	5	11.739	4.30	.001
E x R	67.634	10	6.763	2.48	.007
G x E x R	49.121	10	4.912	1.80	.059
Error	900.075	330	2.758		
Total	3,131.174	431			

Table 3

Proportion of Correct Responses in the Correct Positions After Filled Retention Intervals

Summary of Univariate Analysis of Variance

Source	SS	df	MS	F	p
Groups (G)	315.188	1	315.188	38.87	.001
Encoding Strategies (E)	44.347	2	22.174	2.73	.071
G x E	23.431	2	11.715	1.44	.242
Error	535.181	66	8.109		
Retention Intervals (R)	1,978.466	5	395.693	103.06	.001
G x R	50.521	5	10.104	2.63	.024
E x R	101.458	10	10.146	2.64	.004
G x E x R	96.317	10	9.632	2.51	.007
Error	1,267.068	330	3.840		
Total	4,411.976	431			

Table 4

Number of Errors on the Interpolated Task

Summary of Analysis of Variance					
Source	SS	df	MS	F	p
Groups (G)	2,977.347	1	2,977.347	12.80	.005
Encoding Strategies (E)	1,395.528	2	697.764	3.00	.100
G x E	631.682	2	315.931	1.34	.400
Error	15,348.583	66	232.554		
Total	20,353.320	71			

Appendix B

Task Instructions

Instructions

What I've got for you is a thinking task, which will last a short time today and a short time tomorrow. If you try your hardest and do your best today, you can choose a prize from those you see here. . . And, if you do your best tomorrow you can choose another prize tomorrow. So if you do well on both days, you can end up with two prizes. Before we begin keeping score on today's task, I will give you practice on parts of it to make sure you know what its like and to make sure you understand the rules of the task. If you have any questions during these practice times, just ask me. Before we practice, I want you to read out loud single letters and numbers.

Letter Test

In the center of this TV screen, you'll see single letters of the alphabet--one at a time, in different than the usual order. While a letter is on the screen, I want you to read it out loud to me and then get ready for the next letter to appear. If you don't know which letter is on the screen, just say "I don't know." Okay, now what's going to happen and what are you going to do?. . . And be sure to speak loud enough so I can hear you. Are you ready? . . .Let's begin.

Digit Test

Now in the center of the screen, you'll see single numbers--one at a time, in different than the usual order. While a number is on the screen, I want you to read it out loud to me and then get ready for the next one. If you don't know which number is on the screen, just say "I don't know." Okay, now what's going to happen and, what are you going to do?. . . Are you ready?. . .Let's begin.

Consonant and Strategy Training

Part of the thinking task will be to see if you can remember what letters were on the screen after they disappear. Three letters will be on the screen at the same time. Try to remember all three in order from left to right.

Vocalization condition. While they are on the screen I want you to say all three out loud, two times. If the letters are JYO, you would say "J Y O J Y O." This will help you to do well on the task.

Elaboration condition. While the three letters are on the screen I want you to say out loud a word that begins with the first letter, a word that begins with the second letter, and a word that begins with the third letter. Try to make the second word go with the first word in some way. And try to make the third word go with the second word in some way. So try to say words that belong together in any way. For example, if the letters are TCD, then you might say "truck car driver." If you can't think of words that go together just say any words that begin with the letters. Then all you have to do is remember the words and you automatically will have the letters. Saying words will help you to do well on the task.

Control condition. While they are on the screen I want you to study them. This will help you to do well on the task.

After a short time, the three letters will disappear from the screen. Some time after they disappear, I will want you to remember the letters out loud in the same order that you saw them. Three question marks will appear on the screen when you are supposed to remember the three letters. Some times the three question marks will appear a long time after the letters disappear and sometimes the three question marks will appear right after the letters disappear. If you can't remember a letter, just say the ones that you do remember and say "blank" in the position of the letter that you can't remember. If you can't remember all three letters, just say "I can't remember." After you have tried to remember the three letters, the screen will be blank for awhile. You can rest during this time and clear you mind. As a warning to get ready for the next letters, two stars will appear on the screen and a beeper will beep right before the three letters appear. Okay, now what's going to happen and what are you going to do?. . . Let's try some practice with this now. I'll show you how to do the first one. . . Okay, are you ready?. . .Let's begin.

Digit Training

Another part of the thinking task will be to see if you can read single numbers when they appear one at a time at a fast speed. Let's try some practice with that now. Single numbers will appear on the screen. Read them out loud as you did before. But remember--they will be on the screen for only a short time, so answer as quickly as you can without making mistakes. Sometimes many numbers will appear one at a time at a fast speed and sometimes only a few numbers will appear at a fast speed. Are there any questions?. . . I'll show you how to do the first ones. Are you ready?. . .Let's begin.

Brown-Peterson Training

Now we'll practice doing both the number naming and the letter remembering parts of the task together. When we finally begin keeping score, your task will be to see how well you can do both of these. Right before each group of three letters appears, two stars will appear and a beeper will beep to let you know to get ready. Then, the three letters will appear on the screen. While they are on the screen,

a. study them as you did before.

b. say them out loud two times as you did before.

c. say words that begin with the letters and that go together as you did before.

After the letters disappear, numbers will appear, one at a time. Say each one out loud, as you did before. Say this quickly but without mistakes because the numbers will be appearing at a fast speed. Then three question marks will appear telling you to try to remember the three letters in their correct order. You do not have to remember any numbers, only the letters. The three question marks may appear after many numbers have appeared or they may appear right after the three letters disappear. After you have tried to remember the three letters, the screen will be blank for a short time so you can rest. Then right before the next three letters appear two stars will appear and a beeper will beep again to let you know to get ready. Okay, now what's going to happen and what are you going to do?. . . Let's try some practice with this now. I'll show you how to do the first one. . . Okay, are you ready?. . .Let's begin.

Fine. Now you know what's going to happen and what the rules are. Now we'll start for real. Remember this is to see how well you can do <u>all</u> parts of the task. Do your best. If you do well today, you can pick a prize from those you see here when you finish. And if you do well tomorrow, you can also pick a prize tomorrow.

The Task

Okay, two stars will appear and a beeper will beep before the first three letters will appear. The three letters are what I want you to remember. While the letters are on the screen

a. study them as you did before.

b. say them out loud two times as you did before.

c. say words that begin with the letters and that go together as you did before.

Filled retention intervals. After the letters disappear, numbers will appear one at a time. Say each one out loud as you did before. Remember to say this as quickly as possible without making mistakes because the numbers will be appearing at a fast speed. Then three question marks will appear telling you to try to remember the three letters in their correct order. The three question marks may appear after many numbers have appeared or they may appear right after the letters disappear.

Unfilled retention intervals. Now after the letters disappear, the screen may be blank for some time. Then three question marks will appear telling you to try to remember the three letters in their correct order. No numbers will be appearing in this part of the task. The three question marks may appear after the screen has been blank for a long time or they may appear right after the letters disappear.

If you can't remember a letter, just say the ones that you can remember. If you can't remember all three letters, just say "I can't remember." After the question marks disappear, the screen will be blank for a short time so you can rest before the next stars appear. Don't think of any of the letters in this rest period. Do you have any questions?. . . Try to do the very best you can. Okay, let's begin.

Post-Experimental Inquiry

(a) How did you do this task?

(b) Did you do anything to make the letters easier to remember or were they just there when you needed them?

(c) Were you doing anything when the letters were on the sc een?

Were you doing anything when the numbers were flashing on t screen?

Appendix C

Raw Data

Table 1

Number of Consonants Recalled Regardless of Order (A) and Number of Consonants Recalled in Their Correct Positions (B) Across Filled Retention Intervals by LD Children

Subject	Retention Interval											
	0		3		6		12		18		30	
	A	B	A	B	A	B	A	B	A	B	A	B
1*	12	12	12	12	9	7	10	10	4	0	8	6
2	12	12	11	10	7	6	9	8	6	3	4	2
3	12	12	10	8	9	9	9	9	4	4	9	8
4	12	12	12	12	8	8	5	4	9	9	2	2
5	12	10	11	9	10	8	6	6	3	3	6	5
6	11	11	10	9	5	4	7	5	7	5	7	6
7	12	12	11	10	7	3	7	7	4	4	5	3
8	12	12	11	11	6	3	10	9	9	5	8	7
9	12	10	8	7	8	8	8	6	10	8	8	5
10	12	12	12	12	11	7	7	6	7	6	11	9
11	12	12	12	12	12	12	9	7	9	6	6	6
12	12	10	5	3	3	3	3	2	5	3	4	4
13*	12	12	12	12	9	9	6	5	3	2	1	1
14	12	12	11	11	9	7	7	5	11	11	5	4
15	12	12	8	8	8	7	6	5	6	4	8	7
16	12	12	12	12	6	5	2	2	7	5	6	6
17	12	12	12	12	11	10	5	4	7	7	6	5
18	12	12	12	12	11	11	8	7	5	4	7	7
19	12	12	12	12	12	12	10	8	5	3	7	3
20	12	12	12	12	11	10	4	2	9	7	4	3
21	12	12	11	11	10	10	8	5	8	7	2	1
22	11	9	11	11	10	8	8	6	4	2	3	0
23	12	12	12	12	10	10	3	2	3	2	3	2
24	12	12	10	7	9	7	7	4	8	7	6	3
25*	10	8	12	10	12	12	6	5	9	7	3	3
26	10	9	9	7	6	6	3	2	1	0	5	4
27	10	8	11	6	7	7	8	6	5	5	9	7
28	12	12	12	12	12	12	8	6	6	4	10	10
29	11	9	10	7	8	7	9	7	5	2	6	4
30	12	12	11	11	8	5	11	10	10	10	11	11
31	11	11	12	12	11	11	8	8	5	5	11	11
32	11	11	11	10	7	6	6	5	3	1	7	7
33	12	12	11	11	12	12	10	10	8	6	5	5
34	12	12	9	9	12	12	9	9	10	10	9	9
35	12	10	12	12	12	12	8	5	9	8	3	3
36	12	12	12	12	11	11	12	12	8	8	8	5

*Subjects 1-12 were in the Control Condition, Subjects 13-24 were in the Vocalization Condition, and Subjects 25-36 were in the Elaboration Condition.

Table 2

Number of Consonants Recalled Regardless of Order (A) and Number of Consonants Recalled in Their Correct Positions (B) Across Filled Retention Intervals by Normal Children

Subject	Retention Interval											
	0		3		6		12		18		30	
	A	B	A	B	A	B	A	B	A	B	A	B
1*	12	12	11	10	11	11	8	8	10	9	7	7
2	12	12	10	9	10	10	10	8	10	10	9	9
3	12	12	11	11	9	9	9	8	5	5	7	7
4	12	12	8	5	12	12	9	9	11	10	11	11
5	12	12	12	12	12	12	12	10	8	7	8	8
6	12	12	12	12	8	6	7	7	7	4	10	10
7	12	12	12	12	9	9	11	9	11	10	8	7
8	12	12	12	[illegible]	12	12	9	7	6	6	5	3
9	12	12	12	12	9	9	9	9	11	11	12	12
10	12	12	12	12	11	11	11	9	10	7	6	4
11	12	12	11	11	12	12	10	9	11	9	11	11
12	12	12	12	12	12	12	10	10	10	10	9	9
13*	12	12	11	11	6	6	9	9	4	5	5	5
14	12	12	12	8	10	10	9	5	8	6	6	5
15	12	12	12	12	12	12	9	7	4	12	12	12
16	12	12	10	7	8	7	10	9	5	5	5	4
17	12	12	11	11	11	10	10	10	7	6	6	1
18	12	12	12	12	11	10	12	12	4	9	9	9
19	12	12	11	11	10	10	9	4	8	7	7	4
20	12	12	12	12	11	11	8	7	11	11	10	10
21	12	12	12	12	10	10	10	9	8	6	7	5
22	12	12	10	9	11	10	8	7	7	5	9	8
23	12	12	11	11	11	11	9	9	6	6	8	7
24	12	12	12	10	11	11	11	11	6	5	7	7
25*	12	12	12	12	12	12	10	8	8	7	8	8
26	12	12	12	12	12	12	11	11	11	11	6	6
27	12	12	12	12	10	10	10	10	10	7	9	9
28	12	12	12	12	12	12	11	11	7	6	9	5
29	12	12	12	12	12	12	10	10	8	7	10	10
30	12	12	12	12	12	12	10	9	8	7	7	7
31	12	12	12	12	9	6	10	7	11	7	10	8
32	12	12	12	10	11	8	11	11	6	5	10	9
33	12	12	12	12	12	12	11	11	12	10	7	5
34	12	12	12	12	11	11	9	8	9	8	6	6
35	12	12	11	9	11	11	9	8	6	6	7	3
36	12	12	12	12	12	12	8	5	5	5	11	9

*Subjects 1-12 were in the Control Condition, Subjects 13-24 were in the Vocalization Condition, and Subjects 25-36 were in the Elaboration Condition.

Table 3

Number of Consonants Recalled Regardless of Order (A) and Number of Consonants Recalled in Their Correct Positions (B) Across Unfilled Retention Intervals by LD Children

Subject	Retention Interval 0		3		6		12		18		30	
	A	B	A	B	A	B	A	B	A	B	A	B
1*	12	12	12	12	12	12	12	12	12	12	12	12
2	12	12	12	12	12	12	12	12	12	12	12	12
3	12	12	11	9	11	11	12	12	12	12	12	12
4	12	12	12	12	12	12	12	12	12	12	12	12
5	12	12	12	12	11	10	11	11	12	12	12	12
6	12	12	12	12	12	12	12	10	12	12	10	8
7	11	11	12	12	12	12	11	11	12	10	11	11
8	12	12	12	12	12	12	12	9	12	12	12	12
9	12	12	12	12	11	11	12	12	12	12	12	12
10	12	12	12	12	12	12	12	12	12	12	12	12
11	12	12	12	12	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	10	12	10
13*	12	12	12	12	12	12	11	11	12	12	11	9
14	12	12	12	12	12	12	12	12	12	12	12	12
15	12	12	12	12	12	12	12	12	12	12	12	10
16	12	12	12	12	12	12	12	12	12	12	11	10
17	12	12	12	12	12	12	11	11	12	12	11	11
18	12	12	12	12	12	12	12	12	12	12	12	12
19	12	12	12	12	12	12	12	12	12	12	12	12
20	12	12	12	12	12	12	12	12	12	12	12	12
21	12	12	12	12	12	12	12	12	12	12	11	11
22	12	12	12	12	12	12	12	12	11	11	12	12
23	12	12	12	12	12	12	12	12	12	12	12	12
24	12	12	12	12	12	12	12	12	11	11	11	11
25*	12	12	12	12	11	11	12	12	12	12	12	12
26	12	12	12	12	12	12	12	12	12	12	12	12
27	12	12	11	11	11	11	10	9	12	10	12	12
28	12	12	12	12	12	12	12	12	11	11	12	12
29	12	12	12	12	12	12	12	12	11	11	12	12
30	11	11	12	12	12	12	11	11	12	12	11	11
31	12	12	12	12	12	12	12	12	12	12	12	12
32	12	12	12	12	12	12	12	12	12	12	12	12
33	12	12	12	12	12	12	12	12	10	10	12	12
34	12	12	12	12	11	11	12	12	12	12	12	12
35	12	12	12	12	12	12	12	12	11	11	11	11
36	12	12	11	11	12	12	11	11	12	12	11	7

*Subjects 1-12 were in the Control Condition, Subjects 13-24 were in the Vocalization Condition, Subjects 25-36 were in the Elaboration Condition.

Table 4

Number of Consonants Recalled Regardless of Order (A) and Number of Consonants Recalled in Their Correct Positions (B) Across Unfilled Retention Intervals by Normal Children

Subject	Retention Interval 0		3		6		12		18		30	
	A	B	A	B	A	B	A	B	A	B	A	B
1*	12	12	12	12	12	12	12	12	12	12	12	12
2	12	12	12	12	12	12	12	12	11	9	12	12
3	12	12	10	10	12	12	12	12	12	12	12	12
4	12	12	12	12	11	10	10	10	12	12	12	12
5	12	12	12	12	12	12	12	12	12	12	12	12
6	12	12	12	12	12	12	12	12	11	11	12	12
7	12	12	12	12	12	12	12	12	12	12	12	12
8	12	12	12	12	12	12	12	12	12	12	12	12
9	12	12	12	12	12	12	12	12	12	12	12	12
10	12	12	12	12	12	12	12	12	12	12	11	11
11	12	12	12	12	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12
13*	12	12	12	12	12	12	12	12	12	12	12	12
14	12	12	12	12	12	12	12	12	12	12	12	12
15	12	12	12	12	12	12	12	12	12	12	12	12
16	12	12	12	12	12	12	12	12	12	12	11	11
17	11	11	12	12	12	12	12	12	9	9	12	12
18	12	12	12	12	12	12	12	12	12	12	12	12
19	12	12	12	12	12	12	12	12	12	12	12	12
20	12	12	12	12	12	12	12	12	12	12	12	12
21	12	12	12	12	12	12	12	12	12	12	12	12
22	12	12	12	12	12	12	12	12	12	12	12	12
23	12	12	12	12	12	12	12	12	12	10	12	12
24	12	12	12	12	12	12	12	12	12	12	12	12
25*	12	12	12	12	12	12	12	12	12	12	12	12
26	12	12	12	12	12	12	12	12	12	12	12	12
27	12	12	12	12	12	12	12	12	12	12	12	10
28	12	12	12	12	12	12	12	12	12	12	12	12
29	12	12	12	12	12	12	12	12	12	12	12	12
30	12	12	12	12	12	12	12	12	12	12	12	12
31	12	10	12	12	12	12	12	12	12	12	12	12
32	12	12	12	12	12	12	12	12	12	12	12	12
33	12	12	12	12	12	12	12	12	12	12	11	11
34	12	12	12	12	12	12	12	12	12	12	12	12
35	11	11	12	12	12	12	12	12	12	12	12	12
36	12	12	12	12	12	12	11	11	12	12	12	12

*Subjects 1-12 were in the Control Condition, Subjects 13-24 were in the Vocalization Condition, and Subjects 25-36 were in the Elaboration Condition.

Table 5

Number of Mispronunciations and Omissions on the Interpolated Task by Normal and LD Children

Normal Children		LD Children	
Subject	Errors	Subject	Errors
1*	10	1*	16
2	1	2	12
3	0	3	20
4	37	4	21
5	17	5	29
6	8	6	17
7	16	7	20
8	0	8	20
9	5	9	71
10	19	10	33
11	8	11	16
12	12	12	79
13*	41	13*	49
14	4	14	8
15	15	15	31
16	3	16	25
17	1	17	8
18	1	18	12
19	31	19	7
20	16	20	25
21	4	21	58
22	7	22	6
23	46	23	18
24	6	24	19
25*	11	25*	18
26	9	26	47
27	13	27	16
28	3	28	10
29	5	29	7
30	3	30	2
31	2	31	1
32	7	32	37
33	1	33	8
34	0	34	10
35	0	35	28
36	18	36	4

*Subject 1-12 were in the Control Condition, Subjects 13-24 were in the Vocalization Condition, and Subjects 25-36 were in the Elaboration Condition.

Table 5

Number of Mispronunciations and Omissions on the Interpolated Task by Normal and LD Children

Normal Children		LD Children	
Subject	Errors	Subject	Errors
1*	10	1*	16
2	1	2	12
3	0	3	20
4	37	4	21
5	17	5	29
6	8	6	17
7	16	7	20
8	0	8	20
9	5	9	71
10	19	10	33
11	8	11	16
12	12	12	79
13*	41	13*	49
14	4	14	8
15	15	15	31
16	3	16	25
17	1	17	8
18	1	18	12
19	31	19	7
20	16	20	25
21	4	21	58
22	7	22	6
23	46	23	18
24	6	24	19
25*	11	25*	18
26	9	26	47
27	13	27	16
28	3	28	10
29	5	29	7
30	3	30	2
31	2	31	1
32	7	32	37
33	1	33	8
34	0	34	10
35	0	35	28
36	18	36	4

*Subject 1-12 were in the Control Condition, Subjects 13-24 were in the Vocalization Condition, and Subjects 25-36 were in the Elaboration Condition.

Appendix D

Consonant Trigrams and Their Ratings

Appendix D

Consonant Trigrams and Their Ratings

Table 1

Consonant Trigrams (CCC) and Their Mean Probabilities of Acoustic Confusability (AC) and Association Values (AV) for Days 1 and 2 (Scott & Baddeley, 1969)

Day 1			Day 2		
CCC	AC	AV	CCC	AC	AV
SCP	.33	.67	SPG	.12	.71
MDG	.30	.75	TCH	.34	.75
TKC	.34	.58	BMP	.20	.75
FMS	.32	.67	CGR	.21	.63
CDL	.28	.58	SNF	.31	.58
TRC	.33	.63	BGN	.29	.71
FLS	.32	.75	TCL	.32	.58
CTH	.34	.63	GMD	.30	.58
FSN	.31	.63	SLF	.32	.58
NCT	.34	.58	BDR	.31	.58
PKC	.36	.71	PTH	.35	.75
RDB	.31	.58	DGL	.28	.58
NGP	.27	.58	RTD	.22	.75
BRD	.31	.63	LPC	.32	.63
TPF	.34	.67	PMT	.35	.67
CSH	.23	.67	GDN	.32	.63
GLB	.27	.71	PRT	.33	.58
NDG	.32	.71	FTB	.20	.71
MSF	.32	.58	PKD	.26	.75
DGR	.29	.71	DTH	.24	.58
PTN	.34	.63	BNG	.29	.58
DMB	.32	.71	MPT	.35	.75
GLP	.24	.75	DNG	.32	.58
RDT	.22	.63	PMB	.20	.63

Table 1

Consonant Trigrams (CCC) and Their Mean Probabilities of Acoustic Confusability (AC) and Association Values (AV) for Days 1 and 2 (Scott & Baddeley, 1969)

Day 1			Day 2		
CCC	AC	AV	CCC	AC	AV
SCP	.33	.67	SPG	.12	.71
MDG	.30	.75	TCH	.34	.75
TKC	.34	.58	BMP	.20	.75
FMS	.32	.67	CGR	.21	.63
CDL	.28	.58	SNF	.31	.58
TRC	.33	.63	BGN	.29	.71
FLS	.32	.75	TCL	.32	.58
CTH	.34	.63	GMD	.30	.58
FSN	.31	.63	SLF	.32	.58
NCT	.34	.58	BDR	.31	.58
PKC	.36	.71	PTH	.35	.75
RDB	.31	.58	DGL	.28	.58
NGP	.27	.58	RTD	.22	.75
BRD	.31	.63	LPC	.32	.63
TPF	.34	.67	PMT	.35	.67
CSH	.23	.67	GDN	.32	.63
GLB	.27	.71	PRT	.33	.58
NDG	.32	.71	FTB	.20	.71
MSF	.32	.58	PKD	.26	.75
DGR	.29	.71	DTH	.24	.58
PTN	.34	.63	BNG	.29	.58
DMB	.32	.71	MPT	.35	.75
GLP	.24	.75	DNG	.32	.58
RDT	.22	.63	PMB	.20	.63